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JOURNAL OF PALEONTOLOGY

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VOLUME 25 JANUARY, 1951 NUMBER 1

RICHMOND CONODONTS OF KENTUCKY AND INDIANA

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ABSTRACT—Studies of conodonts from the Arnheim, Waynesville, Liberty, Whitewater, and Elkhorn formations of Kentucky and Indiana, collected by the junior author, add four new genera of complex forms to the known conodonts. Eight new species of well known genera are described and figured.

The collections are sufficiently extensive to show that the stratigraphic distribution of old and new species in the Richmond is usable in age determinations.

STRATIGRAPHY

Rocks of the Richmond group, upper part of the Upper Ordovician, crop out in a roughly circular belt about the Jessamine Dome in southeastern Indiana, southwestern Ohio, and central Kentucky. They, together with the older Maysville group of formations, underlie the Outer Blue Grass, a distinctive soil zone and topographic subdivision. In Indiana and Ohio the formations are primarily composed of phosphatic limestones with lesser amounts of clay or shale. In Kentucky the limestones grade into dolomitic silty beds, which are particularly well developed on the east flank of the dome. The sequence of Richmond formations as they occur in the three special regions about the Jessamine Dome is shown in figure 1.

The Richmond rocks are overlain by the Brassfield dolomitic limestone over most of the area, but are overlapped by Devonian rocks at some places. In the higher portions of the Cincinnati Arch where Richmond rocks remain, the younger beds of the Richmond are missing and Devonian rests upon older members of the Richmond.

The lowest formation of the Richmond, the Arnheim, rests upon the Maysville formation without apparent unconformity. The type locality is at Arnheim, Ohio. Samples from the northern phase were collected near Smith's Crossing (formerly Harmon's Station), Dearborn County, Indiana. This locality is in the Tanner's Creek section of Cumings and Galloway (1913). These samples bear many conodonts and serve as a check on the standard Richmond forms.

East of the Jessamine Dome the Arnheim is divided into two members, the Sunset member below and the Oregonia member above. The sediments are predominantly dolomitic, and consist of silty dolomitic shales in pastel shades of green, blue, and brown, of impure brownish dolomite, and of small amounts of limestone. A thin compact limestone member which is crowded with shells of large ostracodes is considered to be the uppermost bed of the Sunset. Our collections from the Sunset and Oregonia were obtained in the general area of Richmond, Kentucky. The best specimens were derived from a chocolate colored silty dolomitic shale in a cut on the road from Richmond to

Irvine (Kentucky State Highway 52) on the hill east of the reservoir and opposite the N.Y.A. camp.

The Waynesville formation overlies the Arnheim without significant stratigraphic break. The type locality is at Waynesville, Ohio. Here and in Indiana, the formation is predominantly argillaceous, but contains numerous limestone beds. Near Richmond, Kentucky, the formation consists of dolomitic silts with considerable quantities of ferruginous material. Foerste (1909) subdivided the Waynesville into three members, but we were unable to differentiate between these at our collecting localities.

In this area and throughout the northern area of exposure, the Waynesville is overlain by the Liberty formation, named from exposures in Liberty, Indiana. The Liberty consists of cohesive greenish clay with thin, extremely fossiliferous beds of limestone. East of the Jessamine Dome, the beds above the Waynesville consist of ferruginous dolomitic silts and clays and impure dolomites. The rocks are prevailingly light green and weather to dirty yellow-brown shades. Although the entire sequence from the top of the Waynesville to the Brassfield is commonly referred to the Liberty, it may contain rocks of Whitewater age. Its basal contact, that with the Waynesville, is more or less arbitrarily selected. We refer to these highest Richmond beds in the area on the east flank of the Jessamine Dome as "Liberty."

The Liberty formation in the northern and western area of outcrop is overlain by the Whitewater formation, a series of impure phosphatic limestone beds. Samples were collected at the type locality at Whitewater, Indiana, and along the Tanner's Creek section near Weisburg. At Weisburg, the basal beds of the Whitewater contain many specimens of *Tetradium* and are referred to the Saluda member. The Saluda thickens southward and constitutes most of the Whitewater in west-central Kentucky. As stated above, the Whitewater is not recognized on the east flank of the Jessamine Dome.

The highest Richmond formation, the Elkhorn, occurs at the surface over a small area in the vicinity of Richmond, Indiana. The type locality is at and below Elkhorn Falls on Elkhorn Creek, about four miles southeast of Richmond. The formation consists of calcareous shale and impure limestone. At the type locality, the uppermost

OHIO	INDIANA	W. CENTRAL KY.	E. CENTRAL KY.
ELKHORN FM.	ELKHORN FM.		?
WHITEWATER FM.	WHITEWATER FM. / SALUDA MEM.	WHITEWATER FM: / SALUDA MEM.	LIBERTY FM.
LIBERTY FM.	LIBERTY FM.	LIBERTY FM.	
WAYNESVILLE FM.	WAYNESVILLE FM.	WAYNESVILLE FM.	WAYNESVILLE FM.
ARNHEIM FM. OREGONIA MEM. SUNSET MEM.	ARNHEIM FM.	ARNHEIM FM.	ARNHEIM FM. OREGONIA MEM. SUNSET MEM.

FIG. 1—Richmond formations of Ohio, Indiana and Kentucky.

member is a four foot bed of clay immediately beneath the Brassfield dolomitic limestone. It is leached of calcareous matter and is rich in phosphatic material, including conodonts. The clay appears to be residual weathered material from the Elkhorn.

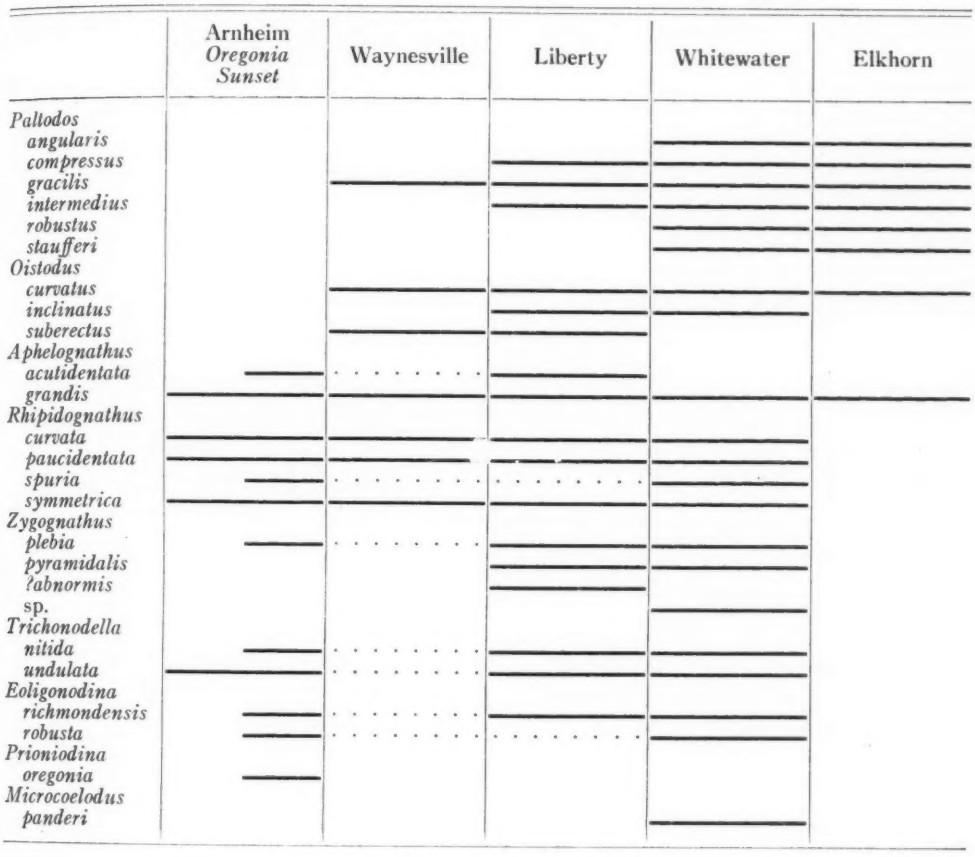
THE RICHMOND CONODONT FAUNA

The authors consider the Richmond fauna, here presented, as representative of the normal conodont habitat of this part of the Ordovician. A large number of samples from many zones, each abundantly filled with conodonts, leaves little to be desired so far as illustrative material is concerned. Each species listed is represented by a sufficiently large number of specimens to give a fair idea of variation possibilities. The authors believe that the stratigraphic distribution of species given in the list comes nearer to presenting a complete picture than has been given in connection with any other Ordovician assemblage. With the exception of one species referred to *Microcoelodus*, no representative of the sub-order Neurodontiformes has been identified in the fauna.

Several genera of the Conodontiformes that are typical of slightly older formations are not representative of the Richmond and some new generic groups appear here for the first time.

Among the published descriptions of conodont assemblages, that of the Maquoketa shale corresponds most nearly with that here described. In general it has been assumed that the Maquoketa is Richmond in

TABLE 1.—STRATIGRAPHIC RANGE OF RICHMOND CONODONT SPECIES



age. However, if the Maquoketa is assumed to be older than the Richmond, there is much less incongruity in the picture of conodont development trends. There are appreciable differences in these two faunas and these are of such nature that they are more easily accounted for by assuming the Richmond is the younger than by attributing them to environmental differences.

The typical Middle Ordovician conodont assemblages are fairly uniform and are typified by forms from the Plattin and the Kimmswick. While the fauna of the latter is well known, only a rather sketchy summary of it has been published by Mehl and Strothmann (1944). A crystalline limestone known as the Fernvale lies between the Kimmswick and Maquoketa in some parts of Missouri and is commonly referred to the Richmond. This age reference has somewhat confused the conodont picture, but it is now known that the Fernvale of Missouri contains a fauna not greatly different from that of the Kimmswick or that of the overlying Maquoketa. There is a normal trend in the faunas from the Plattin, through Kimmswick and Missouri "Fernvale" to Maquoketa, and the Maquoketa fauna is a normal connecting link with the Richmond.

In the chain here mentioned the genus *Belodus* appears up to and including the Maquoketa but is only doubtfully identified beyond. The genus *Phragmodus*, typically in the Plattin and Kimmswick, is represented by a few degenerate, atypical forms in the Maquoketa, and in the Arnheim formation of the Richmond. The genera *Amorphognathus* and *Ambalodus*, common in the mid-Middle Ordovician and up to and including the Maquoketa do not appear in the Richmond faunas described in this paper.

Good specimens representing the genus *Zygognathus* are common in the Arnheim, Waynesville, Liberty, Whitewater, and Elkhorn but no specimens have been identified with certainty either above or below the Richmond.

Rhipidognathus is the most distinctive genus of the Richmond. It is abundant in the Arnheim, Liberty, and Whitewater. It is known from the Maysville, but not from older formations. The genus is not present in the Maquoketa of Missouri.

One of the outstanding features of the fauna is the abundance of specimens and variety of species in the genus *Paltodus*. This group of species and three species of *Oistodus* are the only representatives of the distacodids. *Paltodus* is very abundant in the Whitewater and some specimens have been found in every Richmond formation. Six species are represented in the Richmond fauna. *Oistodus* is present in every Richmond formation of Kentucky. *Trichonodella* is

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EXPLANATION OF PLATE 1

All figures enlarged approximately 25 diameters.

FIGS. *1–8—Paltodus gracilis* Branson and Mehl. *1, 2*, Outer lateral views of two specimens from the Saluda, C746-3, C747-2. *3–6*, Inner lateral, posterior and outer lateral views of three specimens from the Saluda, C746-4. *7*, Inner lateral view of an exceptionally slender specimen from the Liberty, C751-4. *8*, Outer lateral view of a Whitewater specimen, C738-3. (p. 6)

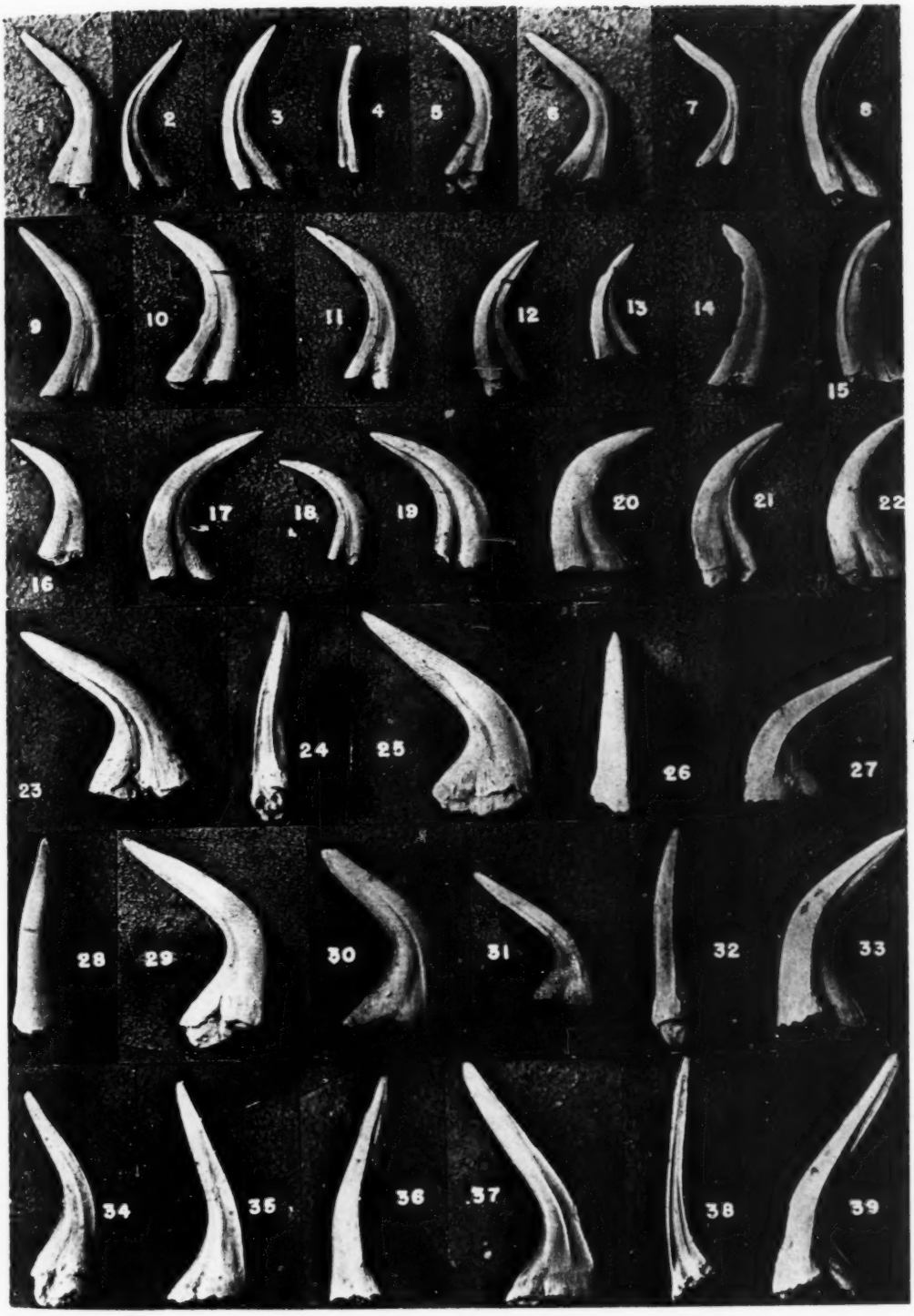
9–15—Paltodus intermedius n. sp. *9*, Inner lateral view of the holotype from the Waynesville, C738-4. *10–12*, Inner lateral views of a paratype from the Saluda, C747-4, and two paratypes from the Saluda, C747-3. *13*, Inner lateral view of a smaller than average specimen from the Liberty C752-4. *14–15* Inner lateral and outer lateral views of a specimen from the Saluda C752-1. (p. 7)

16–22—Paltodus compressus Branson and Mehl. *16 17*, Outer and inner lateral views of two homoeotypes from the Liberty, C751-5. *18, 19, 21, 22*, Three inner views and an outer lateral view of four homoeotypes from the Whitewater, C738-1. *20*, Outer lateral view of a specimen from the Saluda, C747-5. (p. 7)

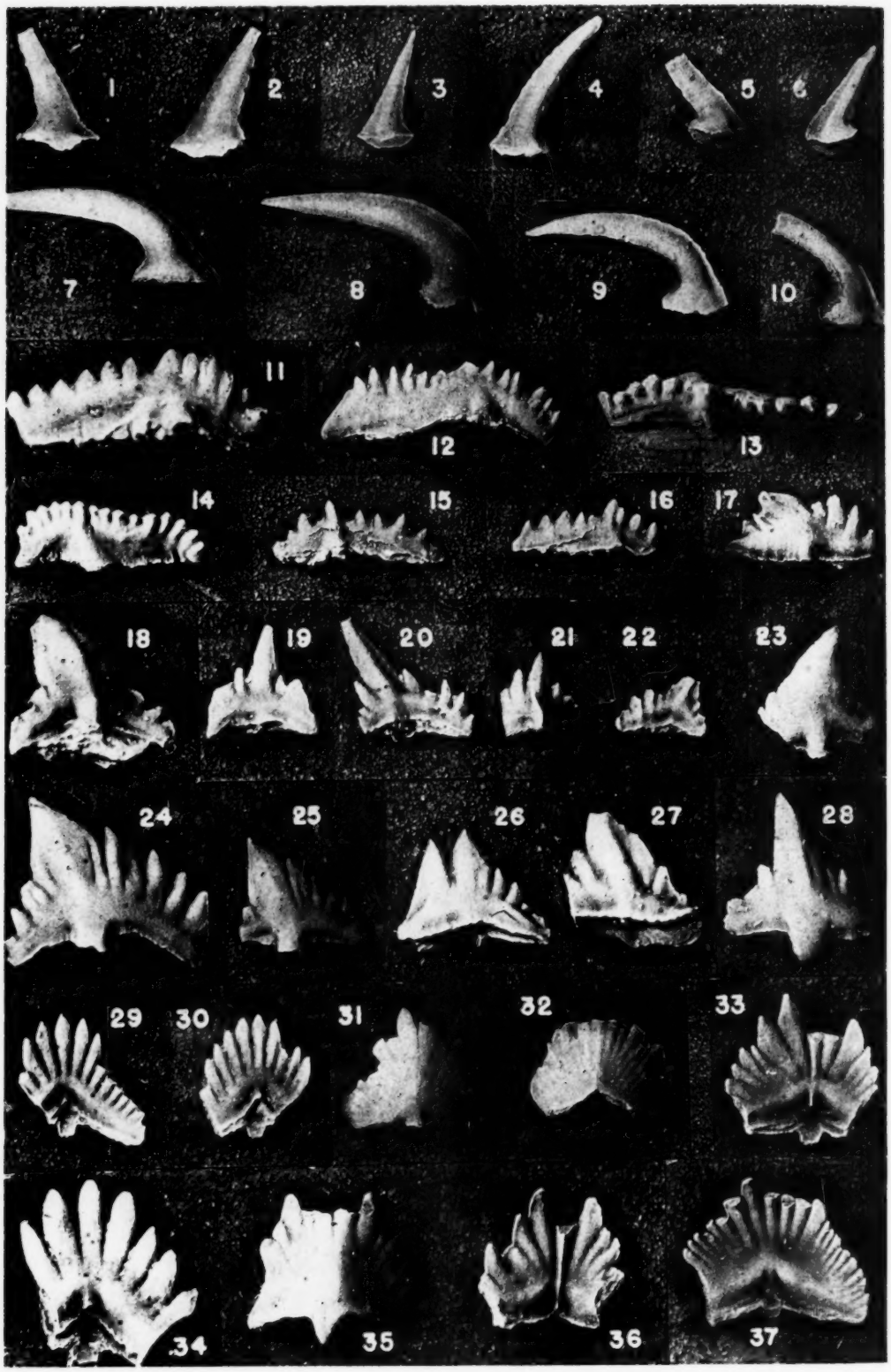
23–27—Paltodus staufferi n. sp. Inner lateral, posterior, outer lateral, anterior, and inner lateral views of four syntypes from the Whitewater, C738-5. (p. 7)

28–33—Paltodus robustus n. sp. *28–32*, Anterior, inner lateral, outer lateral, inner lateral, and posterior views of five syntypes from the Whitewater, C738-2. *33*, Inner lateral view of another specimen from the Whitewater, showing an exceptionally sharp offset, C743-3. (p. 8)

34–39—Paltodus angularis n. sp. *34*, Outer lateral view of a specimen from the Saluda, C748-5. *35–39*, Outer lateral and inner lateral views, and outer lateral, posterior, and inner lateral views of two syntypes from the Whitewater, C743-2. (p. 8)



Branson, Mehl and Branson, Richmond conodonts



Branson, Mehl and Branson, Richmond conodonts

present, but rare, in every formation of the Richmond.

Systematic Descriptions

Family Distacodidae Ulrich and Bassler

Descriptive terminology.—At present all simple cone-like conodonts, excepting those of the Neurodontiformes, are included in the family Distacodidae. For the most part these cone-like forms are small and slender and it is difficult to represent them by accurate cross sections that might be of diagnostic value. The descriptions of forms apparently not closely related may read much the same and with an unstable descriptive terminology and mediocre illustrations, specific identifications from the literature are somewhat uncertain. As there is little immediate hope of determining the exact position and relationship of the cones to the soft anatomy, arbitrary orientation of the cone for descriptive purposes seems desirable.

Few of these teeth approximate a right cone because of some degree of curvature or of inclination to the general plane of the base. This, coupled with the fact that few approach circularity in typical cross section, suggests the following orientation.

For description the cone is visualized as placed on its *basal plane*, the plane formed by the margin of the large or *proximal* end, ignoring minor irregularities. In this position the curved cone presents a longitudinally convex or *anterior* face and an opposite [concave] *posterior* face. The two *lateral* faces are not properly designated as right or left, as in cases of unlike lateral faces the details of the irregularities are reversed in relation to the curvature in some of the otherwise similar cones. If one face is appreciably more ornate than the other, it is arbitrarily designated as the *inner lateral face.* With cones that show bilateral symmetry except for greater lateral expansion at one side of the base, as in *Oistodus*, a lateral curvature of the cone or the difference of basal expansion may be selected as the basis for designating one of the lateral faces as the inner face.

Base is a loose term to be applied to the expanded proximal [excavated] end as opposed to the major part of the piece, in most

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Explanation of Plate 2

All figures, excepting *14* and *34*, enlarged to approximately 25 diameters.

Figs. *1–4—Oistodus suberectus* Branson and Mehl. *1, 2*, Lateral views of two specimens from the Waynesville, C755-1. *3*, Lateral view of a specimen from the Liberty, C750-5. *4*, Lateral view of a typical specimen from the Waynesville, C755-2. (p. 8)

5, 6—Oistodus inclinatus Branson and Mehl. Lateral views of two specimens from the Liberty, C750-2, C750-4.

7–10—Oistodus curvatus Branson and Mehl. *7*, Lateral view of a specimen from the Saluda, C749-1. *8–10*, Lateral views of three specimens from the Liberty, C750-3, C754-2, C750-1. (p. 9)

11–14—Aphelognathus grandis n. sp. *11, 14*, Lateral views of paratype from the Oregonia, C757-1. *12*, Lateral view of paratype from the Whitewater, C739-3. *13*, Oral view of holotype from the Oregonia, C757-5. (p. 9)

15, 16—Aphelognathus acutidentata n. sp. Lateral views of holotype and paratype, from the Oregonia, C757-3, C756-5. (p. 9)

17—Rhipidognathus spuria n. sp. A specimen from the Liberty, less concave posteriorly than average and showing a tendency toward fusion of median denticles, C753-2. (p. 11)

18–28—Rhipidognathus paucidentata n. sp. *18*, Posterior view of a specimen from the Whitewater, C740-3. *19–20*, Anterior views of two specimens from the Oregonia, C756-3. *21*, Posterior view of a deformed specimen from the Oregonia, C755-5. *22*, Posterior view of an immature specimen, C741-5. *23*, Anterior view of a highly modified specimen from the Whitewater, C741-5. *24*, Anterior view of the holotype, C739-2. *25*, Anterior view of a paratype, C740-5. *26–27*, Posterior views of two abnormal specimens from the Whitewater, C741-4. *28*, Anterior view of a specimen from undifferentiated Richmond, C760-5. (p. 10)

29–37—Rhipidognathus symmetrica n. sp. *29, 31, 32, 36*, Posterior, anterior, anterior, and posterior views of four paratypes from the Whitewater, C745-2. *30*, Posterior view of a specimen from the Whitewater, C745-3. *33*, Posterior view of the holotype, from the Whitewater, C744-3. *34–35*, Posterior and anterior views of two specimens from the Oregonia (fig. *34*×17), C760-2. *36*, Posterior view of an Oregonia specimen, C745-2. *37*, Posterior view of a specimen from the Whitewater, C745-1. (p. 10)

cases gradually tapered and designated as the *blade* or *cone*.

The terms *keel* and *carina* have been indiscriminately used for fairly sharp longitudinal ridges, but it is proposed that the term *keel* be confined to such single ridges as mark the anterior or posterior face. Carina may be used to describe a sharp lateral-face ridge.

A *linear depression* with sharp boundaries is commonly designated as a *groove* or *channel*. The term furrow, which has been used commonly in the same sense as groove or channel, might well be confined to fine structural linear grooves like the tight infolding on the inner lateral face of most of the North American specimens referred to the genus *Paltodus*.

The *growth axis* described by Branson and Mehl (1944) and by Furnish (1938) may be designated as median, post-median, or pre-median in position.

With the orientation suggested above, other details of description such as *antero-basal angle* are suggested and self-explanatory.

Genus Paltodus Pander

The specimen and cross sections used by Pander to illustrate this genus emphasize bilateral asymmetry in simple, recurved, deeply excavated, laterally compressed cones with more or less rounded anterior faces, one lateral face smooth and undifferentiated, the other carinate or grooved. Most of the North American species referred to this genus display an infolding of the surface of the more ornate or inner lateral face of the cone to produce a deep, narrow, linear furrow that extends from an emargination of the base to near the tip end of the cone. All such forms have cross-sectional shapes that fall in a general pattern such as would be included in Pander's figures or descriptions. The typical cross section for these forms seems to be somewhat below mid-length (see figure 2).

There is some question as to whether these furrowed forms should be included in the genus *Paltodus*, but no change is suggested before more is known of additional non-furrowed forms that fit Pander's cross-sectional type.

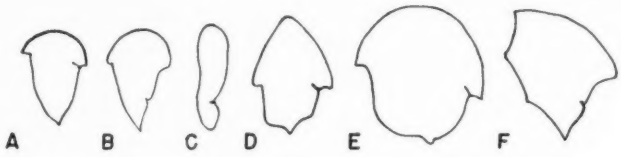

Fig. 2—Typical transverse sections of Richmond species of *Paltodus*. A.—*P. gracilis*, B.—*P. intermedius*, C.—*P. compressus*, D.—*P. staufferi*, E.—*P. robustus*, F.—*P. angularis*.

Paltodus gracilis Branson and Mehl
Plate 1, figures 1–8

Paltodus gracilis Branson and Mehl, 1933, Univ. Missouri Studies, vol. 8, p. 108, pl. 8, figs. 20, 21.

The bracketed words in the following quoted description are introduced to conform with the terminology suggested in this paper.

Long slender cones curved nearly in one plane throughout their length, more sharply near the tip, which is slightly twisted laterally in some specimens. Typically the base is not expanded and is transversely truncate in lateral view so that on the concave [posterior] side of the cone the surface extends appreciably beyond that of the opposite side. The base is excavated by a conical opening that extends through half the length of the tooth. The convex [anterior] side is broadly rounded into the lateral faces. One [the inner] lateral face is marked at about mid-width by a fine groove [furrow], an infolding of the tooth substance, that extends from the base to near the tip. Toward the convex [anterior] side this groove is bordered by a sharp lateral offset, the outer side of which meets the rounded convex [anterior] border. The other lateral [outer] face is slightly convex until it meets a sharp offset or flange similar to that of the opposite side but nearer the convex [anterior] side of the tooth. The concave [posterior] edge of the tooth is sharp.

Remarks.—In general, individuals of this species in the Richmond are more robust than the cotypes and more uniformly

curved. There is a slight variation in the position of the furrow in the later forms.

Homoeotypes.—University of Missouri C738–3, C746–2, C746–3, C751–4, C746–4, C747–2.

Occurrence.—Liberty formation: locality 1881; Saluda member of Whitewater formation: localities 1852 and 1853; Whitewater formation: locality 1844; Elkhorn formation: locality 1847; Waynesville formation: locality 1878; cotypes from the Plattin of New Hope, Missouri.

PALTODUS COMPRESSUS Branson and Mehl
Plate 1, figures 16–22

Paltodus compressus BRANSON and MEHL, 1933, Univ. Missouri Studies, vol. 8, p. 109, pl. 8, fig. 19.

The bracketed words in the following quotation are introduced to conform with the terminology suggested in this paper.

> Cones shorter and wider [of greater anteroposterior measurement] than average, gently curved, except the terminal [distal] third, in the plane formed by the marked lateral compression [posteriorly]. Lateral faces smooth except for a faint median longitudinal groove [furrow] where the tooth substance is infolded on one [the inner] face. The concave [posterior] and convex [anterior] edges are sharp and keel-like. The base is excavated by a symmetrical conical opening [viewed laterally] penetrating half the length of the tooth.

Remarks.—The specimens representing this species in the Richmond are more robust than the Plattin cotypes, are less laterally compressed, and the anterior and posterior sides are more rounded.

Homoeotypes.—University of Missouri C738–1, C747–5, and C751–5.

Occurrence.—Whitewater formation: locality 1844; Saluda member of Whitewater formation: locality 1853; Liberty formation: locality 1882; Elkhorn formation: locality 1847.

PALTODUS INTERMEDIUS Branson, Mehl, and Branson, n. sp.
Plate 1, figures 9–15

Tooth recurved, lateral view outline uniformly tapered from base with nearly uniform curvature of both margins, distal third of anterior margin forming a moderately obtuse angle with base. In cross section anterior side broadly and uniformly rounded into both lateral sides; the inner lateral face flat in posterior half followed anteriorly by a shallow depression that swells out into the anterolateral part; outer face cross section broadly rounded in posterior two thirds to meet the opposite side in a sharp posterior keel, sharply offset outward at one third the width from the anterior edge, thence rounded into anterior face. On the outer lateral face the rounded offset parallels the anterior margin, is most conspicuous near mid-length, and tends to disappear toward both proximal margins, becomes confluent with the offset depression somewhat below mid-length. On the inner face the proximal margin is deeply emarginate near mid-length and the notch extends as a well marked furrow that traverses the flat part of the face and extends nearly to the apex.

Remarks.—One of the most distinctive features of this species is the flat area on the inner face, and another is the fact that the furrow traverses this area instead of being closely associated with a longitudinal trough or sharp lateral offset. Typical specimens of this species are easily distinguished from *P. gracilis* because they are more elongate anteroposteriorly in the mid-length cross section than the latter.

Holotype.—University of Missouri C738–4; paratypes, C747–3, C747–4; homoeotypes, C752–4, C752–1.

Occurrence.—Whitewater formation: locality 1844; Saluda member of Whitewater formation: localities 1853, 1852, 1850; Elkhorn formation: locality 1847.

PALTODUS STAUFFERI Branson, Mehl, and Branson, n. sp.
Plate 1, figures 23–27

Tooth robust, laterally compressed, greatly extended anteroposteriorly at the base, anterobasal angle somewhat less than 90°, sharply recurved at mid-length or less with distal half straight and uniformly tapered, bilaterally symmetrical in its gross features, only slightly twisted, anterolateral faces moderately convex, meeting anteriorly to form a sharply rounded anterior edge which is emphasized in some specimens by bordering slight depressions; posterolateral faces sharply offset inward at about mid-width of the tooth to form sharp shoulders

at their junction with anterolateral faces; moderately convex and meeting posteriorly in a low but distinct keel, furrow starting on inner-lateral face in a deep emargination of the proximal margin somewhat back of mid-width and noticeable back of the lateral offset of that face, joining the depression at the base of the offset at about mid-length of the tooth and continuing in this position to the apex.

Remarks.—This species resembles *P. intermedius* in its posteriorly expanded base but differs most in the sharp anterior edge as contrasted to the broadly rounded anterior face of *P. intermedius*.

Syntypes.—University of Missouri C738–5.

Occurrence.—Whitewater formation: locality 1844; Elkhorn formation: locality 1847.

PALTODUS ROBUSTUS Branson, Mehl, and Branson, n. sp.
Plate 1, figures 28–33

Tooth robust, considerably expanded anteroposteriorly at the base, in gross features bilaterally symmetrical, anterobasal angle from slightly less than to slightly greater than 90°, sharply recurved at or slightly below mid-length, uniformly tapered and nearly straight in distal half, slightly twisted. Anterior face broadly rounded into lateral faces. Posterior part of lateral faces sharply offset inward at about mid-width of the tooth so that the semicircular cross section outline formed by anterolateral and anterior faces ends abruptly in sharp shoulders; posterolateral faces broadly rounded into a sharply offset posterior keel. Inner face deeply emarginate at base at about mid-width to mark the origin of the furrow which is close to and parallels the depression at the base of the sharp shoulder which marks the start of the anterolateral curve.

Remarks.—This species resembles *P. staufferi* in the gross features but differs most in that the anterolateral faces of specimens of the latter meet in a fairly sharp anterior edge. The furrow does not originate as close to the lateral offset in the latter as in *P. robustus*.

Syntypes.—University of Missouri C738–2; homoeotype, C743–3.

Occurrence.—Whitewater formation: locality 1844; Elkhorn formation: locality 1847.

PALTODUS ANGULARIS Branson, Mehl, and Branson, n. sp.
Plate 1, figures 34–39

Tooth slightly twisted, markedly bilaterally asymmetrical, moderately extended posteriorly at base, moderately recurved at a third the distance from the base, beyond which it tapers uniformly and is nearly straight, antero-basal angle 90° or more. Anterior face broadly rounded, meeting lateral faces to form sharp or sharply rounded angles. Inner lateral face flat with anterior half slightly concave and posterior half slightly convex, the furrow about mid-width in position. Outer lateral face broadly convex but consisting of three subequal slightly laterally concave planes, the adjacent boundaries of which form two well marked ridges. Posterior side of tooth sharp to keeled.

Remarks.—This species varies considerably in anterobasal angle and in sharpness of the longitudinal ridges on the outer face. It differs from other known species in the fluted appearance of this face.

Syntypes.—University of Missouri C743–2; homoeotype, C748–5.

Occurrence.—Whitewater formation: locality 1844; Saluda member of the Whitewater formation: locality 1853; Elkhorn formation: locality 1847.

Genus OISTODUS Pander

OISTODUS SUBERECTUS Branson and Mehl
Plate 2, figures 1–4

Oistodus suberectus BRANSON and MEHL, 1933, Univ. Missouri Studies, vol. 8, p. 111, pl. 9, figs. 7–10.

Base flared on all sides to produce lachrymiform, oval, or circular outline, in most specimens more pointed anteriorly than posteriorly, slightly more extended posteriorly than anteriorly; aboral surface excavated by a low conical depression with apex directed slightly forward. Blade very slightly inclined posteriorly and slightly recurved or straight throughout its gently tapering length, laterally compressed, with sharp anterior and posterior edges and moderately convex lateral faces. The entire tooth is nearly bilaterally symmetrical in reference to the plane through the anterior and posterior edges of the blade. Growth axis evident throughout the entire length of most specimens.

Homoeotypes.—University of Missouri C750–5, C755–1, C755–2.

Occurrence.—Liberty formation: locality 1879; Waynesville formation: localities 1878 and 1880; cotypes from the Plattin formation, Salt River, Missouri.

OISTODUS CURVATUS Branson and Mehl
Plate 2, figures 7–10

Oistodus curvatus BRANSON and MEHL, 1933, Univ. Missouri Studies, vol. 8, p. 110, pl. 9, figs. 4, 10, 12.

Base extended both anteriorly and posteriorly, in some specimens more anteriorly. Outer face of base broadly convex and slightly flared, particularly in the posterior part, with aboral outline in lateral view convex in the posterior half. Inner side of base flared in a sharp offset at the base of the cone proper. The base is slightly excavated. The blade is comparatively thin and long, recurved with moderate flexure above the basal expansion, bent slightly inward. The cross section at midlength is moderately convex on the outer side and sharply convex with depressed areas at the ends on the inner side so as to produce sharp anterior and posterior edges that extend across the basal expansion, that of the anterior side forming a thin buttress between the cone proper and the anteriorly expanded base.

Homoeotypes.—University of Missouri, C749–1, C750–3, C754–2, and C750–1.

Occurrence.—Saluda member of the Whitewater formation: locality 1852; Liberty formation: localities 1881 and 1884; Waynesville formation: locality 1880; Elkhorn formation: locality 1848. The species was described from the Plattin of Salt River, Missouri. Cotypes—University of Missouri C106–5.

GENUS APHELOGNATHUS Branson, Mehl, and Branson, n. gen.

Elongate, sheath-like teeth, straight or laterally sinuous and more or less arched. Blunt oral edge produced, with discrete low denticles nearly circular in cross section; one of which, commonly the largest, marks the highest point, typically not at mid-length. Aboral edge laterally flaring and deeply excavated, particularly wide and deep near mid-length with diminishing excavation toward the termini. Lateral walls thin, expanded laterally to half-cones below the largest denticle.

Genotype.—Aphelognathus grandis Branson, Mehl, and Branson, n. sp.

For descriptive purposes the short end is considered posterior to the apical denticle and in specimens that are not laterally straight the generally concave side is the inner side.

This group has much in common with that described by Stauffer under the name *Bryantodina* but the latter has laterally compressed denticles with sharp edges and the aboral part is not deeply excavated.

Fundamentally there is little to distinguish this genus from *Dichognathus* except that in typical specimens of that group the expansion below the main denticle is sharp and its denticles are more or less sharp edged. Some Plattin species of *Dichognathus* approach the typical aphelognathids. It is likely that the aphelognathids are an outgrowth of the dichognathids, but in their typical development the dichognathids are Middle Ordovician in age and the aphelognathids are Upper Ordovician and they are sufficiently distinctive as groups to be of stratigraphic value.

APHELOGNATHUS GRANDIS Branson, Mehl, and Branson, n. sp.
Plate 2, figures 11–14

Base of dental unit slightly sinuous, sides converging to a sharp crenulate edge on the oral margin, flaring downward to aboral margins; inner sides bearing craterlike half cone, outer side with a pair of half-cones. Oral edge produced into 10–18 blunt, short, subequal denticles, about five of which are on the posterior part.

Holotype.—University of Missouri C757-5; paratypes C757-1, C739-3.

Occurrence.—Oregonia member of the Arnheim formation: locality 1778; Whitewater formation: locality 1846; Sunset member, Arnheim formation: locality 1857; Waynesville formation: locality 1878; Liberty formation: localities 1879, 1881; Saluda member, Whitewater formation: locality 1852; Elkhorn formation: locality 1847.

APHELOGNATHUS ACUTIDENTATA Branson, Mehl, and Branson, n. sp.
Plate 2, figures 15, 16

Dental unit nearly straight, obtusely triangular in cross section; short, pointed, with eight to ten widely-spaced denticles, one at about a third the length from posterior end

distinctly larger than the others. A single basal flare on inner side only. Base deeply excavated, with thin walls making straight basal margins.

Holotype.—University of Missouri, C756-5; paratype, C757-3.

Occurrence.—Oregonia member of the Arnheim formation: locality 1778.

Genus RHIPIDOGNATHUS Branson, Mehl, and Branson, n. gen.

Erect dental units; more or less palmate, flat or concave posteriorly, fundamentally bilaterally symmetrical with slightly excavated or channeled aboral surface nearly straight to highly and sharply arched. Denticles more or less anteroposteriorly compressed, blunt to sharply pointed, rounded or sharp edged, partially fused, particularly near mid-width of unit. Posterior face of unit commonly marked by a short ridge, normal to the base, and by a transverse swelling, at the base of the denticles, parallel to but distinct from the aboral edge. Anterior aboral edge of base commonly produced into a small trowel-like process with the concavity or pit of attachment on the posterior side.

Genotype.—*Rhipidognathus symmetrica* Branson, Mehl, and Branson, n. sp.

Remarks.—Some species of this genus closely resemble some of the representatives of the genus *Leptochirognathus*, but the laminar structure of *Rhipidognathus* seems to place the genus in the suborder Conodontiformes rather than in the fibrous Neurodontiformes to which *Leptochirognathus* belongs. The aboral edge of the leptochirognathids is only slightly excavated, if at all, and is commonly found attached to jaw material typical of the neurodontiformids, a kind of material not noted in the conodontiformids. The discrete, circular cross section denticles of *Chirognathus* distinguish that genus from the species with flat denticles of the genus *Rhipidognathus*.

RHIPIDOGNATHUS SYMMETRICA Branson, Mehl, and Branson, n. sp.
Plate 2, figures 29–37; Plate 3, figure 31

Bilaterally symmetrical, posteriorly concave units with closely crowded to fused denticles varying from about 16 to 30 in number. Anterior aboral outline from slightly to sharply arched with a mid-width aboral projection and postero-aboral outline more deeply emarginate at mid-width to produce a large attachment surface at mid-width that continues laterally as a narrow trough. Posterior face commonly marked by a sharp ridged extension of the median denticle across the basal portions of the tooth. The marked variations in number of discrete denticular termini seem only in part due to fusion of units.

Holotype.—University of Missouri C744-3; paratypes, C745-2; hypotypes, C745-3, C760-2, C745-5.

Occurrence.—Whitewater formation: localities 1849, 1846, 1845, 1844; Oregonia member of the Arnheim formation: locality 1778.

RHIPIDOGNATHUS PAUCIDENTATA Branson, Mehl, and Branson, n. sp.
Plate 2, figures 18–28; Plate 3, figure 30

Sturdy units moderately arched, bilaterally subsymmetrical, with one limb noticeably larger than the other, thickened at the base of the denticles on both anterior and posterior faces but with thin aboral edges, denticles compressed, sharp edged, more or less confluent with a tendency to fuse laterally. One denticle longer and wider than the others, consisting of several fused units, rises from the apex of the arch and all denticles tend to parallel it. Long limb of arch bearing about twice the number of denticles as the short limb, probably eight to ten but in some cases fused into a single crenulate oral edge. Attachment facet variable but well developed, extending aborally in line with the apical denticle.

Holotype.—University of Missouri C739-2; hypotypes, C740-3, C741-5, C740-5, C741-4, C760-5, C755-5, C745-4.

Occurrence.—Whitewater formation: localities 1846, 1844; Oregonia member of the Arnheim formation: localities 1778, 1812.

RHIPIDOGNATHUS CURVATA Branson, Mehl, and Branson, n. sp.
Plate 3, figures 1–7

Thin delicate bilaterally asymmetrical units, regularly curved transversely, concave posteriorly with slightly arched aboral margin. Antero-aboral marginal outline interrupted by the markedly off-center at-

tachment projection. Oral edge set with about twelve compressed, sharp-edged, sharp pointed, closely crowded to partly fused denticles of which one or more of greater size marks the portion of the attachment pit and to one side of which there are about half as many of the remaining denticles as on the other side. The posterior surface is marked by a swelling or ridge at the base of the denticle that parallels the aboral margin but is distinct from it.

Remarks.—The chief variation noted in representatives of this species is a tendency toward somewhat smaller, more numerous and less compressed denticles than in the type.

Syntypes.—Four specimens, University of Missouri, C756-4; hypotypes, C760-3, C743-1, C759-1.

Occurrence.—Oregonia member of Arnheim formation: locality 1778; Whitewater formation: localities 1844, 1849, 1845; Sunset member of the Arnheim formation: locality 1857; Saluda member, Whitewater formation: locality 1852.

RHIPIDOGNATHUS SPURIA Branson, Mehl, and Branson, n. sp.
Plate 2, figure 17; Plate 3, figures 8, 9

Dental unit small, bilaterally subsymmetrical, somewhat laterally curved, aboral margin straight or slightly arched in anterior view with a very slight mid-width modification by the spout-like structure. About eight denticles, compressed, short, divergent, subequal.

Holotype.—University of Missouri C740-1.

Occurrence.—Whitewater formation: locality 1844; Saluda member, Whitewater formation: locality 1852.

RHIPIDOGNATHUS sp. undet.
Plate 3, figure 29

Dental unit massive, bilaterally asymmetrical, slightly arched, with one or two large flat denticles rising from the apex and inclined toward the shorter limb. On the long limb are about eight denticles, about twice as many as on the short limb, all tending to parallel the main denticle. The base is strongly curved upward. The basal attachment process projects beyond the aboral margin in line with the main denticle.

This form has much in common with *R. curvata* Branson, Mehl, and Branson, and may represent a senile development of that form. However, intermediate stages between the two have not been noted.

Figured specimen.—University of Missouri C744-5.

Occurrence.—Whitewater formation: locality 1844.

Genus ZYGOGNATHUS Branson, Mehl, and Branson, n. gen.

Deeply excavated cone-like denticulate units that tip the distal ends of the somewhat compressed jaw rami and continue beyond the cone base for variable distances as a sheathing bar on each of the two edges of the ramus. The denticle terminating the cone, compressed and sharp edged to nearly circular in transverse section, curves orad and stands nearly erect. The bar that sheathes the oral edge of the ramus bears pointed, laterally compressed, discrete, erect denticles that lie in the same plane as the terminal denticle, and tend to parallel it. The inferolateral sheathing bar, commonly the longer of the two, has the free edge directed in a nearly perpendicular plane to that of the oral edge bar, bears inclined, discrete denticles that vary in cross section and are directed inward and slightly forward.

Genotype.—*Zygognathus pyramidalis* Branson, Mehl, and Branson, n. sp.

Orientation.—A large proportion of the specimens representing *Zygognathus* show clearly the relationship of the clasping unit to the jaw ramus. However, as the relationships of the rami to each other and to the oral cavity may be questioned, arbitrary descriptive terminology that implies a definite orientation is suggested. The recurved cone tip is the fang and the basal sheathing bar that lies in the plane of its curvature is designated as the oral or oral-edge bar. The other basal extension is the inferolateral bar that marks the inner side of the unit.

Relationships.—There is little fundamental difference between *Zygognathus* and *Pteroconus* but the denticulate wings of the latter are on the base of the cone proper and do not resemble the bar-like sheathing extension from the cone base of the former. Some of the less typical representatives of

Microcoelodus, which is typically bilaterally symmetrical, resemble some of the zygognathids but, like the pteroconids, do not show distinct proximally extending sheathing bars. In typical forms of *Zygognathus* the denticulate extensions are less bar-like and the angle between them is smaller than in *Eoligonodina*. In *Zygognathus* the main denticle and its basal extensions do not lie in a plane but indicate a jaw ramus that is sharply curved in transverse section, and the denticles are on the inside.

ZYGOGNATHUS PYRAMIDALIS Branson, Mehl, and Branson, n. sp.
Plate 3, figures 10–16, 21

Terminal denticle much larger than the others, suberect, anteroposteriorly compressed with sharp edges, rapidly tapered to a moderately sharp point. Oral edge bar only slightly produced beyond base of cone, bearing six or more low, moderately pointed, conical denticles closely crowded at their bases. Inferolateral bar extending well beyond base of cone, bearing eight or more short, somewhat compressed denticles that are directed inward and slightly forward and tend to fuse laterally.

In this species the thin-walled basal cone is proportionally much larger than that of *Z. plebia* and does not have as pronounced a mid-width posterior extension of the base on each face of the ramus between the two basal bars.

Holotype.—University of Missouri, C744-1: hypotypes, C753-5, C739-4, C741-2, C746-1.

Occurrence.—Whitewater formation: localities 1846, 1844; Liberty formation: locality 1882; Saluda member, Whitewater formation: locality 1852.

ZYGOGNATHUS PLEBIA Branson, Mehl, and Branson, n. sp.
Plate 3, figures 22, 23; Plate 4, figures 1–9

Terminal denticle considerably larger than the others, relatively short, nearly

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EXPLANATION OF PLATE 3

All figures except figure *2* enlarged approximately 25 diameters.

FIGS. *1–7*—*Rhipidognathus curvata* n. sp. *1*, Posterior view of an incomplete specimen from the Oregonia, C760-3. *2*, Posterior view (×17) of a specimen from the Whitewater, C743-1. *3*, Outer view of an average specimen from the Oregonia, C759-1. *4–7*, Anterior, posterior, posterior, and posterior views of four syntypes from the Oregonia, C756-4. (p. 10)

8, 9—*Rhipidognathus spuria* n. sp. Anterior views of a young specimen from the Saluda, C748-2, and of the holotype from the Whitewater, C740-1. (p. 11)

10–16, 21—*Zygognathus pyramidalis* n. sp. *10*, Inner view of C753-5, Liberty formation. *11*, Inner view of a specimen from the Whitewater, C739-4. *12, 14*, Anterior and inner views of two specimens from the Whitewater, C741-2. *13, 15*, Anterior and inner views of two specimens from the Whitewater, C742-4. *16*, Inner view of a Saluda specimen, CC746-1. *21*, Inner view of the holotype, C744-1, Whitewater. (p. 12)

17—*Eoligonodina robusta ?* Inner lateral view of a specimen from the Whitewater, C742-3. (p. 15)

18—*Prioniodina oregonia* n. sp. Outer view of one of the syntypes, C757-4. (p. 15)

19—*Oulodus* sp. indetermined. Inner lateral view of the single specimen from the present study referable to this genus, too fragmental for specific identification, Liberty formation, C753-4.

20—*Zygognathus ? abnormis* n. sp. Inner view of the holotype, Liberty, C753-3. (p. 14)

22, 23—*Zygognathus plebia* n. sp. *22*, Aboral view of a specimen, C754-1, Liberty formation. *23*, Oral view of the holotype, C743-4, Whitewater formation. (p. 12)

24, 25—*Trichonodella undulata* n. sp. *24*, Posterior view of holotype, C739-5, Whitewater formation. *25*, Posterior view of a specimen, C740-4, Whitewater formation. (p. 14)

26—*Trichonodella undulata ?* Posterior view of a specimen with smaller than typical angle between lateral limbs, Whitewater formation, C744-4. (p. 14)

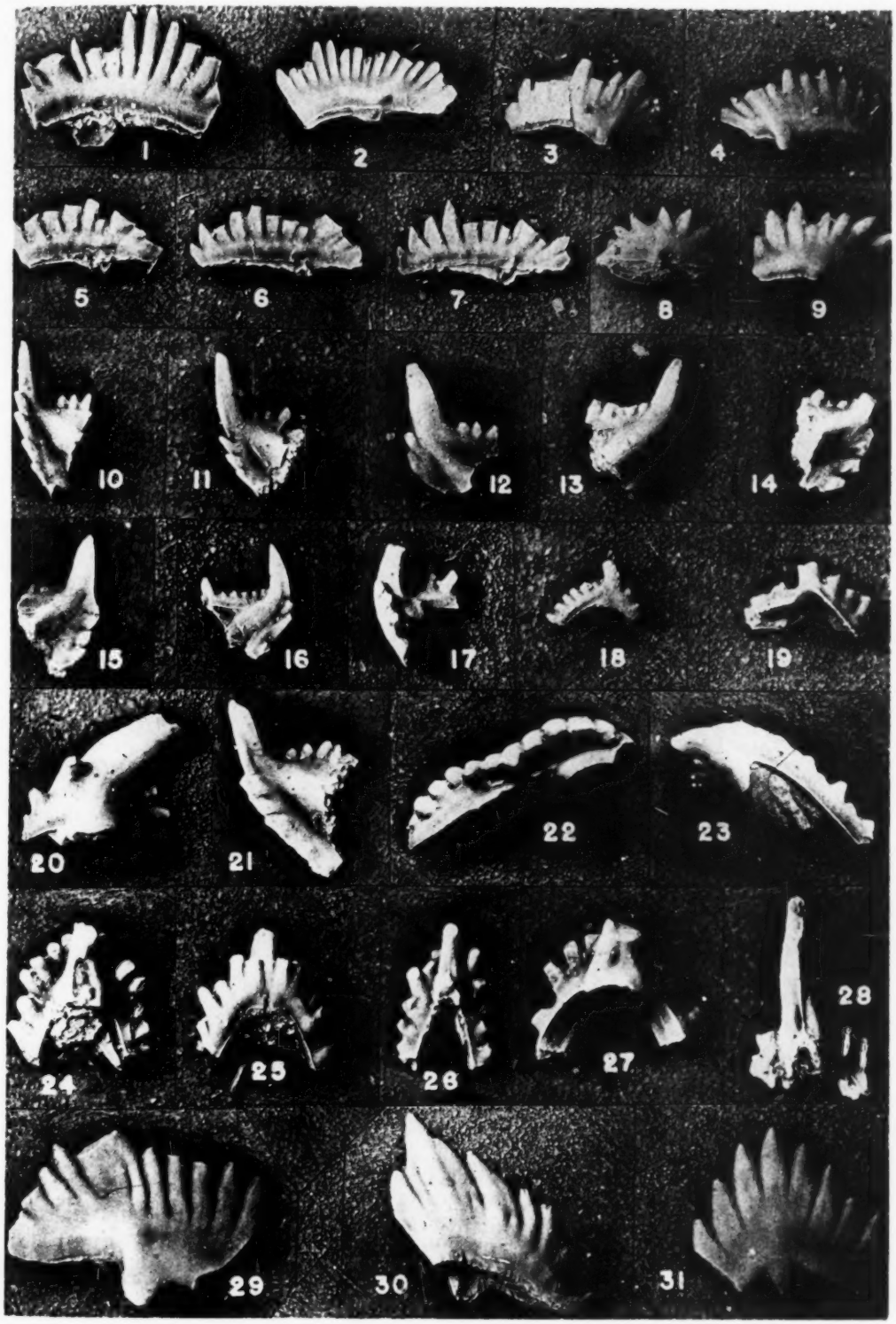
27—*Trichonodella ?* sp. Posterior view of a specimen, C741-1, from the Whitewater. (p. 14)

28—*Trichonodella* sp. Back view of a large incomplete specimen, C760-1, from the Oregonia.

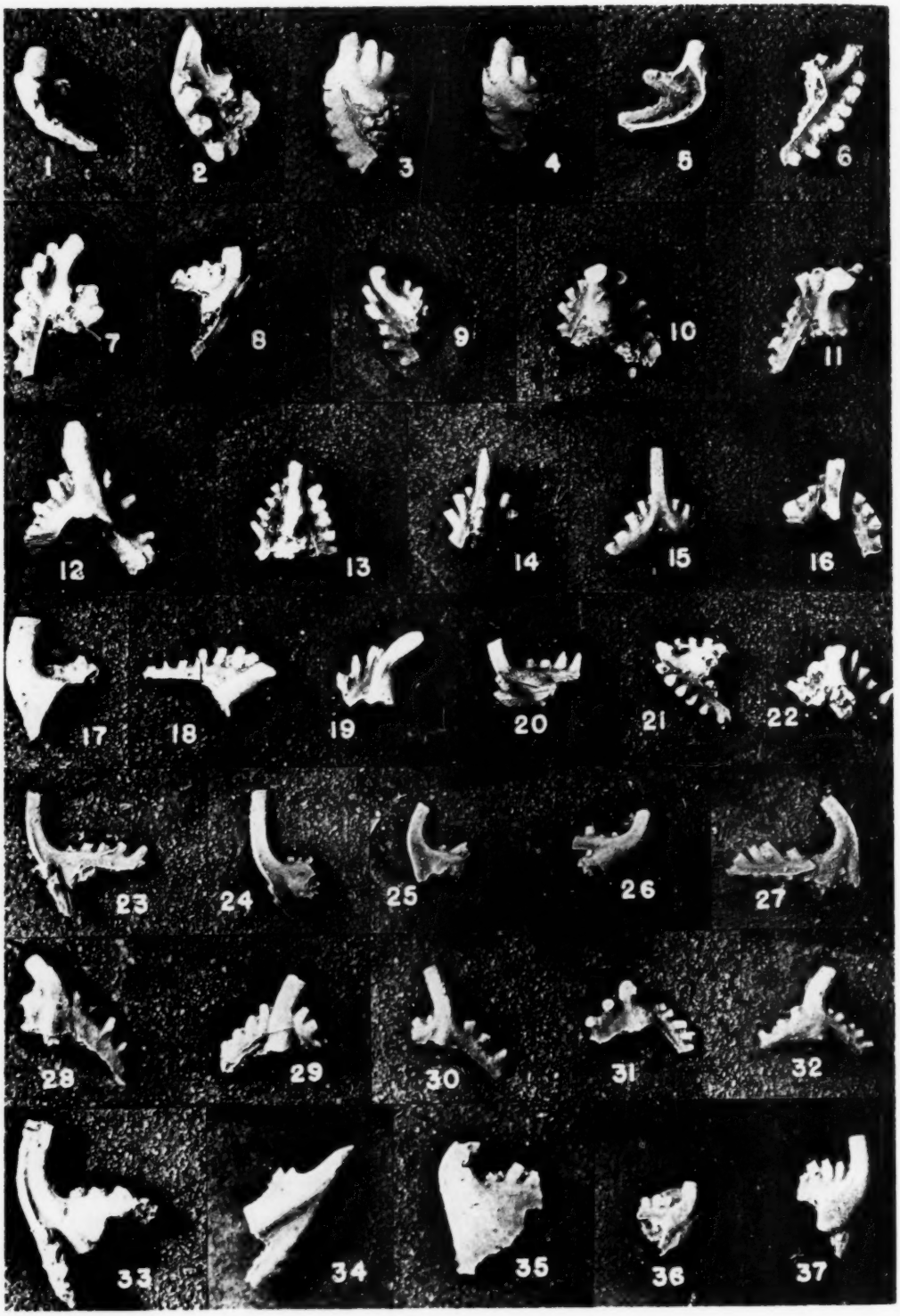
29—*Rhipidognathus* sp. undetermined. Details of anterior side of an incomplete, exceptionally large specimen, C744-5, from the Whitewater.

30—*Rhipidognathus paucidentata* n. sp. Posterior view of an incomplete specimen, C745-4, from the Whitewater formation. (p. 10)

31—*Rhipidognathus symmetrica* n. sp. Anterior view of an incomplete specimen, C745-5, from the Whitewater formation, showing typical denticulation and basal extension. (p. 10)



Branson, Mehl and Branson, Richmond conodonts



Branson, Mehl and Branson, Richmond conodonts

circular in basal cross section. Oral edge bar much shorter than inferolateral bar, denticles short, nearly erect, subcircular, closely crowded to confluent at the base, somewhat irregular in size and irregularly divergent. Inferolateral bar denticles 10 or more, similar to oral edge denticles, in general directed laterally.

No available specimens of this species are complete, but it is clear that the inferolateral bar averages fully twice the length of the oral edge bar. A considerable number of specimens of zygognathids have features much like those of the holotype, but average much smaller. Similar specimens of intermediate size have not been found, so that the differences in the two groups can not be definitely considered to be age differences, although this seems possible.

Holotype.—University of Missouri C743-4; hypotypes, C754-1, C761-2, C761-5, C758-4.

Occurrence.—Whitewater formation: locality 1844; Liberty formation: locality 1883. Questioned specimens from the Oregonia member of the Arnheim formation: locality 1778.

ZYGOGNATHUS sp.
Plate 4, figures 13, 18–21, 34

From several Richmond localities have come many specimens clearly referable to the genus *Zygognathus* but not referable to a described species. The specimens are more delicately constructed than normal and few are sufficiently well preserved to justify specific reference. The members of the group are variable particularly in their symmetry, many approaching bilateral symmetry. The bar denticles are subequal, of moderate length, subcircular and discrete to clearly separated at their base. The main denticle is slender and strongly curved inward. Apparently the limbs are subequal in length, long and slender.

Figured specimens.—University of Missouri C741-3, C742-1, C742-2, C756-1, C743-5.

Occurrence.—Saluda member, Whitewater formation: locality 1846 (Figures 13, 18, and 19); Oregonia member, Arnheim formation: locality 1778; Whitewater formation: locality 1844.

EXPLANATION OF PLATE 4

All figures enlarged approximately 25 diameters.

FIGS. *1–9—Zygognathus plebia ?* Several specimens that represent a smaller than average group that is otherwise similar to the type of *Z. plebia*. *1–5*, Inner aboral, inner outer aboral, and outer views of five specimens, C761-2, from the Oregonia. The inferolateral bar in fig. *1* and the oral bar in fig. *5* are broken away to show the sheathing nature of the basal excavation and bars. *6*, Inner lateral view of an Oregonia specimen, C761-5. *7–9*, Oral views, slightly inner lateral and posterior; outer lateral; and inner lateral views of three Oregonia specimens, C758-4, which approach bilateral symmetry. (p. 12)

10, 11, 22—Trichonodella undulata n. sp. Posterior views of two specimens, C758-2, and a third specimen, C761-1, from the Oregonia: locality 1778. (p. 14)

12—Microcoelodus panderi n. sp. Posterior view of the holotype, C744-2, Whitewater formation. (p. 16)

13, 18–21—Zygognathus sp. *13, 18, 19*, Inner views of three specimens, C741-3, from the Whitewater. *20, 21*, Inner views of two specimens, C742-2, C756-1, from the Oregonia. (p. 13)

14—Trichonodella undulata ? Posterior view of a specimen, C740-2, Whitewater formation. (p. 14)

15–16—Trichonodella nitida n. sp. *15*, Posterior view of the holotype, C758-5, from the Oregonia. *16*, Posterior view of a specimen, C755-3, from the Waynesville. (p. 14)

17—Cordylodus sp. ? Inner lateral view of a specimen, C755-4, from the Waynesville.

23–27—Eoligonodina richmondensis n. sp. *23*, Inner lateral view of holotype, C759-3, from the Oregonia. *24*, Inner view of a specimen, C758-1, from the Oregonia. *25–27*, Inner, outer and inner views of three specimens, C759-2, from the Oregonia. (p. 15)

28–32—Prioniodina oregonia n. sp. *28, 29, 31*, Outer, outer, and inner lateral views of three specimens, C761-1, from the Oregonia. *30, 32*, Outer lateral views of two syntypes C757-4 from the Oregonia. (p. 15)

33, 35–37—Eoligonodina robusta n. sp. *33*, Inner lateral view of holotype, C756-2, *35*, Outer lateral view of a large specimen, C739-1, from the Oregonia. *36, 37*, Outer lateral views of two specimens, C742-5. Whitewater formation. (p. 15)

34—Zygognathus sp. Outer lateral view of an incomplete specimen, C743-4, showing an exceptional development of the terminal denticles, Whitewater formation. (p. 13)

ZYGOGNATHUS? ABNORMIS Branson, Mehl, and Branson, n. sp.
Plate 3, figure 20

Terminal denticle exceptionally large, laterally compressed, with convex faces meeting in sharp anterior and posterior edges. Denticles of oral edge bar laterally compressed, sharp edged, confluent to near their apices. Inferolateral bar aborted, scarcely produced beyond the base of the cone, bearing about three discrete, relatively short, slightly compressed, irregularly directed denticles.

Only one fairly well preserved specimen representing this species is available for specific analysis. The absence of a real inferolateral bar in this specimen leaves some doubt as to whether it should be referred to the genus *Zygognathus*.

Holotype.—University of Missouri C755-3.

Occurrence.—Liberty formation: locality 1879.

Genus TRICHONODELLA Branson and Mehl
TRICHONODELLA NITIDA Branson, Mehl, and Branson, n. sp.
Plate 4, figures 15, 16

Delicate units with long, slender, subcircular, regularly recurved, posteriorly carinate apical denticle; lateral limbs straight or slightly arched, forming an angle of about 110°. Oral edge set with slightly anteroposteriorly compressed to sharp edged denticles, discrete to slightly separated, about 11 to a millimeter, aboral edge of bars slightly excavated. Posterior bar short, pointed, edentate, directed somewhat aborad. Unit markedly excavated on aboral side at union of limbs in a triangular outlined concavity.

Remarks.—No complete specimens have been found, but the lateral bar denticles are probably comparatively long and slender. The posterior carina of the apical denticle is commonly centrally placed and variable in development, but long in most specimens, evident near the base and extending along the posterior bar.

Holotype.—University of Missouri C758-5; hypotype, C755-3.

Occurrence.—Oregonia member, Arnheim formation: locality 1778; Waynesville formation: locality 1821; Liberty formation: locality 1882; Whitewater formation: locality 1844.

TRICHONODELLA UNDULATA Branson, Mehl, and Branson, n. sp.
Plate 3, figures 24–26; Plate 4, figures 10, 11, 14, 22

Apical denticle prominent, subcircular, sharply recurved, with a marked concavity on its posterior surface just above the juncture with the posterior bar. Lateral bars stout, diverging at an angle of about 50°, aboral surfaces transversely flat with sharp edges, oral edge with discrete but closely crowded, subequal, somewhat irregularly directed circular denticles that tend to extend beyond the bars proper to the anterior base of the apical denticle so as to crowd in front of it; the length of the bars undetermined, denticles about eight per millimeter, all curved posteriorly. Posterior bar very short, directed as much aborad as back, wide at the base, oral surface bearing one to a few short peg-like denticles, aboral surface flat. Union of limbs forming a relatively large shallowly concave aboral surface beneath the apical denticle. One of the most distinctive features of this species is the tendency of the lateral limb denticle to extend across the arch in front of the apical denticle. Many specimens differ from typical representatives in that the apical angle of the lateral limbs averages about 30° but there are gradations between this and the typical apical angle and little else to distinguish specimens representing the extremes.

Holotype.—University of Missouri C739-5; hypotypes, C758-2, C761-1, C754-1; questioned specimens, C744-4, C740-2.

Occurrence.—Whitewater formation: locality 1844; Oregonia member of Arnheim formation: locality 1778.

Genus EOLIGONODINA Branson, Mehl, and Branson, n. gen.

Complex dental units consisting of a relatively long, slender, recurved terminal denticle with deeply excavated thin-walled base expanded in the plane of the curvature and extended on the oral edge into a denticulate bar, at approximately a right angle to the denticle; from the opposite anteroaboral edge of the expanded base the main

denticle is continued as a denticulate bar in the same plane as the denticle and its other denticulate bar and bears denticles directed about normal to this plane.

Descriptive terminology and orientation.—This piece is conceived of as tipping and partially clasping the individual jaw ramus with one basal branch (the posterior bar) extending horizontally as a denticulate bar on the oral edge of the ramus, the other extending along the antero-aboral edge of the ramus, which terminates in the deep basal excavation of the terminal denticle, or fang. Jaw material is commonly preserved in the thin-walled base. The aboral extension of the terminal denticle is the antero-aboral process. The denticulate side of the process marks the inner side of the unit.

Genotype.—*Eoligonodina robusta*, n. sp.

Relationships.—*Eoligonodina* is similar to *Cordylodus* Pander and to *Cyrtoniodus* Stauffer in their gross features but differs in that in neither of the latter two is there an indication of a distinct antero-aboral denticulate bar. The most conspicuous difference between *Eoligonodina* and *Ligonodina* Ulrich and Bassler is the absence of a deeply excavated thin-walled base in the terminal fang of the latter. *Eoligonodina* and *Zygognathus* have much in common and atypical specimens of each are not satisfactorily distinguishable. In typical forms of *Zygognathus* the inferior bar does not lie in the same plane as that of the curved fang but indicates a transversely curved jaw ramus, concave inward. The angle between the two bars is smaller on the average in *Zygognathus* than in *Eoligonodina*.

EOLIGONODINA ROBUSTA Branson, Mehl, and Branson, n. sp.
Plate 4, figures 33, 35–37

Moderately robust with basal cup less laterally compressed and its inner and outer free margins more or less lobate. Terminal denticle relatively long and slender, recurved above base, straight and erect in its terminal half; subcircular in cross section with a distinct sharp ridge near the anterior edge of the inner face. Posterior bar not greatly compressed, about as wide as deep at aboral edge, aborally excavated, length undetermined, probably relatively short, set with short, subcircular, closely crowded but discrete denticles erect or slightly inclined posteriorly. Antero-aboral process comparatively short, set with about four short conical subcircular discrete denticles directed inward.

This species is more sturdy than *E. richmondensis* and has a more lobate inner and outer free margin of the basal cup, and the posterior bar denticles are more nearly erect.

Holotype.—University of Missouri C756-2; hypotypes, C739-1, C742-5.

Occurrence.—Oregonia member, Arnheim formation: locality 1778; Whitewater formation: locality 1846.

EOLIGONODINA RICHMONDENSIS Branson, Mehl, and Branson, n. sp.,
Plate 4, figures 23–27

Delicate units with long slender fang, sharply recurved above base and erect in its major length. Fang somewhat laterally compressed with rounded faces except for a distinctly sharp antero-inner edge. Posterior bar laterally compressed, nearly straight, deeply excavated, aborally set with discrete, moderately long, subequal, circular cross sectioned, posteriorly inclined denticles, presumably six to eight in number. Length of antero-aboral process about equally divided between base of fang and aboral free projection, set with about four short discrete laterally inward-directed denticles. Free margin of basal cup not lobate.

Holotype.—University of Missouri C759-3; hypotypes, C759-2, C758-1.

Occurrence.—Oregonia member, Arnheim formation: locality 1778.

PRIONIODINA OREGONIA Branson, Mehl, and Branson, n. sp.
Plate 3, figure 18;
Plate 4, figures 28–32

Highly arched and somewhat laterally sinuous, the short limb concave inward, the long limb straight. Apical denticle long and slender, laterally compressed with sharp edges, flared inward at the base, curved inward and slightly posteriorly, much longer than limb denticles. Short limb bearing three or four closely crowded to widely spaced, laterally compressed short denticles which are normal to the limb. Long limb

apparently about twice as long as shorter limb, bearing short, subequal closely crowded denticles that are subcircular in section, all inclined slightly posteriorly. Aboral edge deeply excavated with concavity extending to and beyond mid-length of the limbs.

Syntypes.—Three specimens, University of Missouri C757-4; hypotypes, C761-1.

Occurrence.—Oregonia member, Arnheim formation: locality 1778.

MICROCOELODUS PANDERI Branson, Mehl, and Branson, n. sp.
Plate 4, figure 12

Apical denticle stout, relatively short, recurved and somewhat twisted dextrally, anteroposteriorly compressed with sharp lateral edges, base produced posteriorly into a stout tongue-like process; lateral limbs somewhat twisted, bearing short closely crowded to confluent subcircular sharply conical denticles that are irregularly directed, aboral edge slightly concave transversely; unit deeply excavated beneath apical denticle.

Remarks.—This species, in its general appearance does not depart radically from some specimens of *Trichonodella undulata*, but the jaw material of *Microcoelodus panderi* is typical of the suborder Neurodontiformes and very different from that of the trichonodellids. This species is the only representative of the Neurodontiformes noted in the collection presented in this study.

Holotype.—University of Missouri C744-2.

Occurrence.—Whitewater formation: locality 1846.

RICHMOND CONODONT LOCALITIES

ARNHEIM formation
Sunset member
1820. Bank just north of Kentucky Highway 52 opposite entrance to N.Y.A. camp, three miles east of Richmond, Clark County, Kentucky.
1839. Cut on Kentucky Highway 89 about eight miles south of Winchester, Clark County, Kentucky.
1857. Just below the ostracode bed, one mile south of Agawam Station along the railroad, Clark County, Kentucky.
Oregonia member
1641. Stratigraphic level not certain. Road cut in Bath County, Kentucky (collected by Russell Farmer).
1643. Stratigraphic level not certain. Road cut in Bath County, Kentucky (collected by Russell Farmer).
1778. Upper part of brown dolomitic silt, in cut on north side of Kentucky Highway 52 three miles east of Richmond, Clark County, Kentucky.
1812. Same locality. Lower part of the brown silt.
1803. Clay in middle of road cut on Kentucky Highway 40, three miles east of Mt. Sterling, Montgomery County, Kentucky.

WAYNESVILLE formation
1821. Greenish dolomitic siltstone in cut on United States Highway 227 near Red House, Madison County, Kentucky.
1878. Upper part of the formation. Taken in creek bank next to Cut 16 of the Tanner's Creek section on the Big Four Railroad, about two miles south of Weisburg, Dearborn County, Indiana.
1880. Lower part of the formation. Upper part of Cut 13 of the Tanner's Creek section on the Big Four Railroad, near Harmon's (now Smith's Crossing), Dearborn County, Indiana.
1909. Greenish dolomitic siltstone eight feet above base of the formation, railroad cut south of Agawam Station, Clark County, Kentucky.

LIBERTY formation
1779. "Liberty" greenish dolomitic silt about fifty feet below the Brassfield dolomite on hill road leading north from Kentucky Highway 52 about five miles east of Waco, Estill County, Kentucky.
1780. Same locality. Sample from immediately below the Brassfield dolomite.
1877. "Liberty" dolomitic siltstone about fifteen feet below the Brassfield dolomite, in road cut on east side of Kentucky Highway 89, half a mile north of the Red River bridge, Clark County, Kentucky.
1879. Road cut on north side of highway one mile west of Liberty, Union County, Indiana.
1881. Cut on road by the water works, three miles east of Osgood, Ripley County, Indiana.
1882. Fifteen feet below the *Tetradium* bed, in cut on north side of United States Highway 50 in east edge of Versailles, Ripley County, Indiana.
1883. Upper part of the formation. Creek bank three miles east of Hamburg, Franklin County, Indiana.
1884. Lower Liberty. Cut on road over old steel bridge, one mile south of Richmond, Wayne County, Indiana.
1885. "Liberty" greenish siltstone in middle of cut on east side of Kentucky Highway 89 on hill above Red River bridge, Estill County, Kentucky.

1886. Twenty feet below the *Tetradium* bed. Five feet below sample 1882 at same locality.

WHITEWATER formation

1670. Highest beds exposed along United States Highway 50 in east edge of Versailles, Ripley County, Indiana.

1844. Purple shale above Saluda and below green siltstone in cut on north side of United States Highway 50, east edge of Versailles, Ripley County, Indiana.

1845. Ten feet below top of mottled rubbly limestone, same locality as 1844.

1846. Basal Whitewater, just above the *Tetradium* beds in Cut 18 of the Tanner's Creek section along the Big Four Railroad, near Weisburg, Dearborn County, Indiana.

1849. Middle of mottled rubbly limestone bed, ten feet below locality 1845.

1850. Lower part of the Saluda member near the Liberty contact, in road cut near the old steel bridge one mile south of Richmond, Wayne County, Indiana.

1851. Beds exposed next to Thistlewaite Falls, Richmond, Wayne County, Indiana.

1852. Saluda member, dark shale just below principal *Tetradium* layer, in Cut 18 of Tanner's Creek section on Big Four Railroad, Weisburg, Dearborn County, Indiana.

1853. Upper part of Saluda member, in cut on United States Highway 50 in east edge of Versailles, Ripley County, Indiana.

ELKHORN formation

1847. About twenty-five feet below the top of the Elkhorn formation in the twelve-foot shale bed below twenty feet of limestone in the thirty-foot cliff three quarters of a mile below Elkhorn Falls, on Elkhorn Creek, three miles southeast of Richmond, Wayne County, Indiana.

1848. Blue clay at top of Elkhorn in recess below Brassfield dolomite ledge which forms the lip of Elkhorn Falls, three miles southeast of Richmond, Wayne County, Indiana.

MANUSCRIPT RECEIVED JANUARY 12, 1950.

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JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 1, PP. 18–20, PL. 5, 1 TEXT FIGURE, JANUARY 1951

PETRIFIED FOREST IN SOUTH-WEST AFRICA

ROBERT J. RODIN
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ABSTRACT—A petrified forest occurring in the (Permian) Ecca series was recently discovered in the Kaokoveld, South-West Africa. It contains many large logs in a good state of preservation which have proved to be *Dadoxylon Arberi* Seward.

INTRODUCTION

THE recent discovery of an extensive petrified forest in South-West Africa by Dr. Charles L. Camp, Director of the University of California African Expedition in South Africa, has been a valuable contribution to our scanty knowledge of petrified wood in South Africa.

Dr. Camp went into the area of Doros Crater in the Kaokoveld seeking additional fossil materials of the reptile *Mesosaurus*, discovered there by Reuning (Du Toit, 1939, p. 301). He noticed the Karroo beds extending farther north and went to examine them. On the farm of Jan H. Oberholzer (farm 62), 34 miles southwest of Franzfontein and about 40 miles northeast of Doros Crater, he found the largest petrified forest yet known in southern Africa. One area contained more than 10 acres of fossil logs in an excellent state of preservation. He examined the occurrence and obtained several specimens. Later I visited the area and collected additional material.

With the aid of Dr. Ralph W. Chaney at the University of California and Dr. R. Kräusel of Senckenberg Museum, Frankfurt, Germany, I have found that the new forest is composed largely, if not entirely of *Dadoxylon Arberi* Seward. Dr. Camp has given valuable assistance in interpreting the geology of the area.

HISTORICAL SKETCH

During the last decade little paleobotanical work has been done on material from South-West Africa. Alexander du Toit (1939, pp. 298, 316) has mentioned several species of *Dadoxylon* found there. According to him it occurs in the Dwyka series (Lower Permian?) at Kabus, from whence silicified wood was collected and referred to *D. scleroticum* Gothan by Gothan. It was placed in that series because it was associated with *Mesosaurus*.

From the Ecca series (Permian) Du Toit reported *Dadoxylon Arberi* Seward from Van Wyks Vlei, in southwest Cape Province; *D. porosum* Kräusel and *D. Rangei* Kräusel from South-West Africa. He lists *D. Arberi* Seward as also occurring in the Lower Beaufort series (Late Permian) at Murraysburg, Philipstown, and Umkomaas Valley in the Union of South Africa. He has listed other *Dadoxylon* species as late as the Molteno Zone of the Stormberg series (Upper Triassic). Du Toit does not mention the occurrence of *Dadoxylon Arberi* Seward in South-West Africa.

A paper by Kräusel and Range (1928), the most complete study of fossil woods in South-West Africa, mentions ten gymnosperms. The four species of *Dadoxylon* listed from South-West Africa are as follows: *D. Arberi* Seward from Doros Crater and Umgebg; *D. porosum* Kräusel from Keetmanshoop, Huns and Aurus; *D. Rangei* Kräusel from Gibeon, Keetmanshoop, Goamus, Huns, Aurus, Mukorup, Berseba, Fish River and Gaibes; and *D.* sp., cf. *Abietopitys perforata* (Gothan) Kräusel, source unknown.

Previous to Kräusel and Range there had been considerable work done on *Dadoxylon Arberi* Seward by John Walton (1925). He attempted to illustrate this species and included a careful description, as the original type specimens were not adequately figured (Arber, 1905, pp. 191–199, figures 40–43). Walton lists as synonyms of *D. Arberi* Seward the following species: *D. australe* Arber, *D.* cf. *angustum* Felix, *D. Nicoli* Seward, and *D. Bakeri* Walton. These identifications are all based on secondary wood and specimens other than secondary wood must therefore be given different names.

Dadoxylon Arberi Seward has been found in Australia, Falkland Islands, and South Africa. Because of its wide southern distribution, this species may yet be found in South America.

DESCRIPTION

The petrified forest is apparently in an ancient river channel. Erosion by the present stream has exposed many of the logs and left numerous broken pieces scattered about. The petrified trees, lying horizontally, are as much as four feet in diameter and at least two trees are fully exposed which I paced and found to be approximately 150 feet long. Although the trunks are broken into sections six feet long or shorter, the segments are still in place. Several hundred different logs are partly or completely exposed, appearing as if they had drifted into their present position in the old stream gravel. All have straight trunks that taper gradually. The whole forest apparently consists of a single species; however further work on material brought back may reveal more than the one species already studied.

The wood has been silicified and agatized except for some parts which are filled with lime. The color varies from brown with white streaks, to red with light colored streaks; some pieces are pure white. Presence of annual growth rings of varying thicknesses indicates that these trees grew in a seasonal climate of pronounced rainfall variation. Cell structure was well preserved in all the specimens cut. There was a predominance of red color in the sections studied. The uni- or bi-seriate wood rays vary from a few to many cells as seen in tangential sections (plate 5, figures 4, 5). In a radial section the large round bordered pits are arranged alternately in one to three rows, but usually two (plate 5, figure 2). In some sections the pore is visible in the bordered pits but the torus does not seem to be preserved. In cross-section the thick-walled wood cells appear somewhat compressed, probably due to pressure of overburden before petrification (plate 5, figure 3).

In certain radial sections (plate 5, figure 6) abnormal developments can be seen which may be due to a fungus infection. Kräusel and Range (1928) make no men-

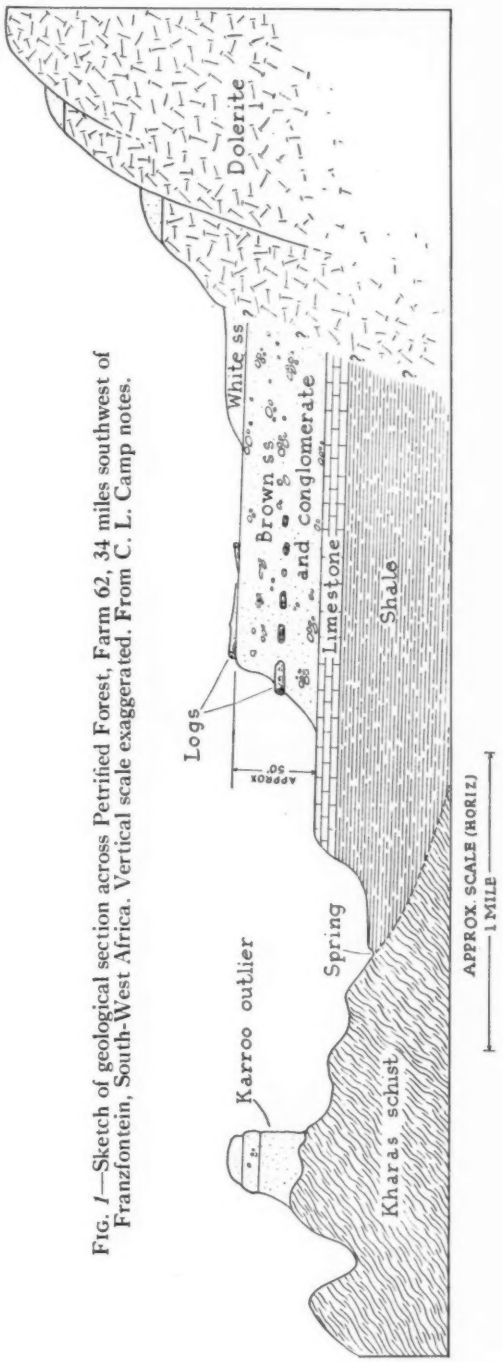

FIG. 1—Sketch of geological section across Petrified Forest, Farm 62, 34 miles southwest of Franzfontein, South-West Africa. Vertical scale exaggerated. From C. L. Camp notes.

tion of fungi. In a recent letter Kräusel[1] states that from photographs sent by me, he is not certain whether the objects are fungi or inorganic material. However, Walton (1925, p. 15) states that a fungus with "resinous inclusions" is present in some parts of the wood of *Dadoxylon sclerosum* Walton, from South African collections. Walton's sections had mycelia and a few are visible in our material. He makes no attempt to identify the fungus, stating only that it can be seen in tracheids lying parallel to the medullary rays. Our slide material is also prepared from a radial section and appears to have darkened globules associated with the rays.

Among modern gymnosperms the mycelia of various fungi penetrate tracheids and wood rays. As the growth progresses to another area of the tree, the hyphae undergo autolysis and disappear from the area of earlier infestation. During the period of activity the metabolic processes were disturbed, frequently causing deposits of resins and other waste materials in the cells. It is possible that the dark globules may be due to such byproducts. Further evidence of the presence of a fungus is the breaking down of cell walls in the preserved wood in the areas where these dark globules occur. Because the mycelia for the most part are no longer visible, it is assumed that they have been digested.

From Dr. Camp's field book we have the following notation: "The matrix carrying the logs is a mass of cross-bedded sandstone, some with quartz pebbles rounded and polished, up to 2 inches in diameter, brownish in color on the surface, full of quartz pebbles and gravel, quite hard, and about 50 feet in thickness. This is very much the same as the layer carrying logs at Doros Crater except that I could not find any fish scales or teeth in adjacent levels. It lies on the extremely rough eroded surface of the Kharas schists and is near the base of the 'Karroo' beds in this vicinity" (Text figure 1).

The petrified forest consists of the same species as found in the Upper Ecca series (Permian) in many localities in South Africa. It has been determined by Kräusel and Range (1928, p. 44) that the same species from nearby Doros Crater was from the Ecca, and Walton (1925, p. 5) says that this species is found only in the Ecca. Reuning (1923) on his geological map of South-West Africa, did not indicate an outcrop of Karroo in that part of the Kaokoveld where the petrified forest is located. Kräusel and Range (1928), on the map accompanying their publication, indicate small occurrences of the Karroo northeast of Doros Crater where the new petrified forest is located. In the light of previously reported occurrences and our present knowledge of the geological formations of this area, we can logically conclude that this occurrence of *Dadoxylon Arberi* Seward is in the Ecca series (Permian).

[1] Personal communication April 16, 1949.

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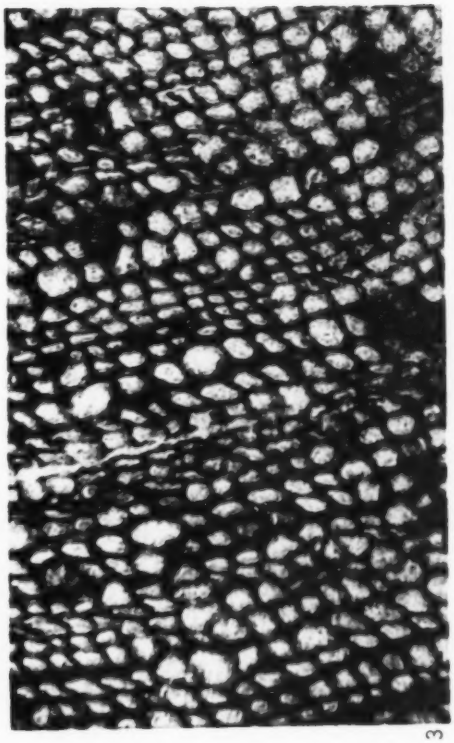
EXPLANATION OF PLATE 5

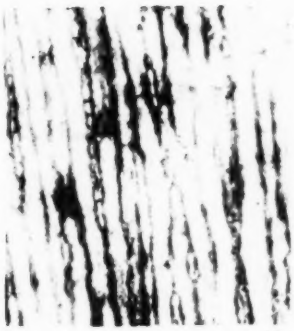
Figure *1* was photographed at the Petrified Forest on Farm 62, 34 miles southwest of Franzfontein, South-West Africa. Figures *2–6* are from material collected there.

FIG. *1*—Scattered pieces of petrified logs. (p. 19)

2–6—*Dadoxylon Arberi* Seward. *2*, radial section showing round bordered pits of tracheids and adjacent ray cells, ×375. *3*, cross section of secondary wood, ×100. *4*, tangential section to show a wood ray, ×375. *5*, tangential section to show an area containing wood rays, ×50. *6*, radial section showing globules apparently due to a fungus infection, with cell walls somewhat broken, ×50. (p. 19)

MANUSCRIPT RECEIVED JANUARY 10, 1950.





Rodin, Petrified forest in Southwest Africa

JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 1, PP. 21–30, PLS. 6–10, JANUARY 1951

PERMIAN CALCAREOUS ALGAE FROM THE APACHE MOUNTAINS, TEXAS

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ABSTRACT—Algae occur through a considerable thickness of beds in the Apache Mountains. Locally they are so abundant as to be the main constituent of the limestones. The forms described include red algae (*Solenopora*), green algae (both Codiaceae and Dasycladaceae), and lower tubular and filamentous forms. Dasycladaceae are the most abundant and include not only *Mizzia* but several other genera, including *Diploporella* and *Gyroporella*, not previously reported from strata older than Triassic. Of special interest is the occurrence of several species of the genus *Gymnocodium*, as this is common in most areas of Permian deposits but has not been previously described from the Western Hemisphere.

INTRODUCTION

THE presence of calcareous algae in the Permian rocks of west Texas has been known for a considerable time, but until recently no attempt has been made to study them.

During the summer of 1939, a party of geologists from Midland, Texas, took the author on a tour through the Apache Mountains to collect fossil algae. The party consisted of J. E. Adams, R. K. DeFord, R. King, K. Ferguson, and E. H. Stevens. Several interesting localities were visited, and considerable material was collected. At that time the author was working on Permian material from the Guadalupe Mountain region. He published the results of that study (Johnson, 1942), but was prevented from continuing his studies of Texas material by the war. However, during the war years several visits were made to the area and additional material collected. Because of present interest in the reef limestones of the region, these data have been assembled for use by those working in the region.

About 300 specimens and 100 slides have been studied. The type and figured specimens are in the Johnson collection at the Colorado School of Mines, Golden, Colorado. Thanks are due Merle K. Johnson and Mrs. W. F. Dukes for assistance in preparing the manuscript and reading proof. The Colorado School of Mines supplied laboratory and photographic facilities and thin sections for this work.

GEOGRAPHICAL DISTRIBUTION AND AGE

The specimens were obtained from several localities in the Apache Mountains. However, most of them were collected along the western side just south of Seven Heart Gap, Culberson County, Texas.

Foraminifera occur with the algae, the most abundant being a large fusulinid. These were examined by M. L. Thompson (personal correspondence, Jan. 23, 1941), who states: "It is a representative of the genus *Polydiexodina* Dunbar and Skinner . . . closely related, if not identical to the type specimen of *P. shumardi* D. and S. This was described from the upper part of the Delaware Mountain formation. . . . Dunbar and Skinner seem to think the species is restricted to the Delaware Mountain formation."

CLASSIFICATION

Upper Paleozoic algae have been classified as shown in Table 1. Representatives of all these groups except the Laminariales and the Charophyta have been recognized in specimens from the Apache Mountains. The *Solenopora*, Dasycladaceae, Codiaceae, and Prostromata show recognizable microstructure as well as a definite shape of colony; therefore, they are the most satisfactory to work with. In the collections studied the Dasycladaceae and Codiaceae are the most abundant forms present.

TABLE 1.—CLASSIFICATION OF UPPER PALEOZOIC ALGAE
(After Johnson, 1946)

Class	Family	Characteristic Structures
Rhodophyta (Red Algae)	Solenoporaceae	Rows of closely packed cells with polygonal cross sections. Cross partitions present though frequently very thin.
Phaeophyta (Brown Algae)	Laminariales and others (?)	Corded strands of parallel threads (as in framework of *Archimedes* Hall). Fronded types.
Chlorophyta (Green Algae)	Charophyta	Highly developed small bushy plants. Fossils usually consist of calcified heavily ribbed spherical oogonia and the whorled branches which bear them.
	Dasycladaceae	A central stalk, preserved as a tube or bulb, surrounded by tufts or leaves or leaf bases, preserved as knobs or brush-like protuberances.
	Codiaceae	Small tubes loosely arranged so as to form segmented stems. Tubes round in cross section and branching.
Cyanophyta (Possibly Chlorophyta)	Porostromata	Small tubes so loosely arranged as not to compress each other. No cross partitions visible.
Cyanophyta (Blue Green Algae)	Spongiostroma	Cellular structure seldom preserved. The $CaCO_3$ is deposited as crusts on the outside of the colony or cell, or between the tissues, not in the cell wall. Classified on the basis of growth habit and form of the colony.

SYSTEMATIC DESCRIPTIONS

Class RHODOPHYTA
Order FLORIDEAE
Family SOLENOPORACEAE
Genus SOLENOPORA Dybowski
SOLENOPORA CENTURIONIS Pia
Plate 1, figures 1, 2, 3

Solenopora sp., PIA, 1937, p. 835, pl. 10, figs. 1–3.
Solenopora centurionis PIA, 1940, p. 3.
Solenopora centurionis JOHNSON, 1942, p. 200, pl. 1, figs. 3–6.

Pia's original description is essentially as follows: Thallus forms irregular, often lobate, nodular masses 1 to 4 centimeters in diameter. Texture dense, usually concentrically banded with fine dark lines between bands. In cross section the cells appear more rounded than angular. Originally the walls were probably thick. Diameter of cells 0.03 to 0.04 mm. Thickness of cell walls about 0.01 mm. No transverse partitions observed, possibly as a result of poor preservation.

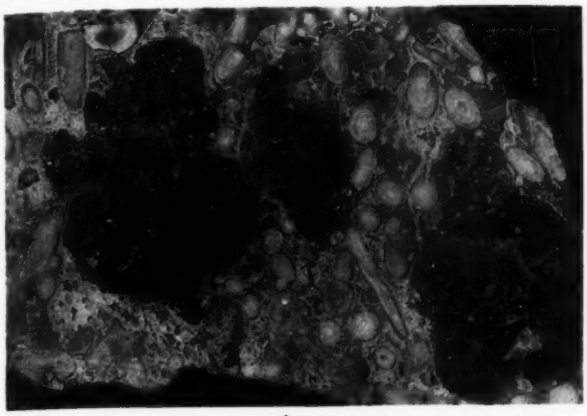
The writer would add the following observations: Cells long and slender, fairly uniform in width. Transverse sections round to hexagonal. No cross partitions visible. Cell measurements—width in longitudinal sections, 0.033 to 0.048 mm.; width transverse section, 0.028–0.039 mm. Wall thickness 0.01 to 0.015 mm.

Figured specimens.—Slide 796 and specimens JA2852 and 3116, Johnson collection, Colorado School of Mines.

Remarks.—Several specimens belonging to this species were observed. It was also found in the Guadalupe Mountain area (Johnson, 1942, p. 200).

EXPLANATION OF PLATE 6
Solenopora

FIG. *1*—*Solenopora centurionis* Pia. Specimens in rock with Foraminifera (*Polydiexodina*). ×1½. (p. 22)
2—*Solenopora centurionis* Pia, showing microstructure. ×40. (p. 22)
3—*Solenopora*, probably *S. centurionis* in a *Mizzia* limestone. ×3. (p. 22)
4–5—*Solenopora texana* Johnson, n. sp., showing details of microstructure. ×40. (p. 23)



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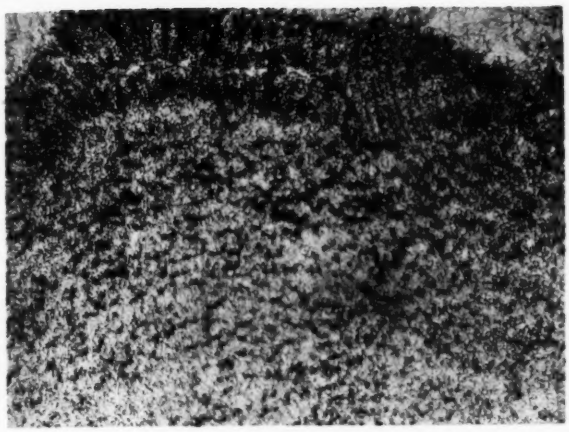

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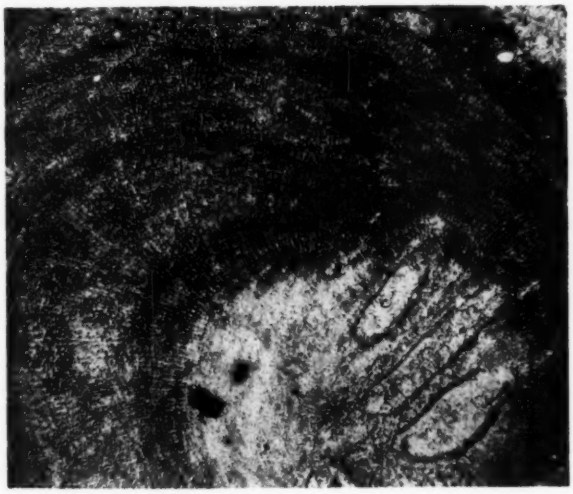

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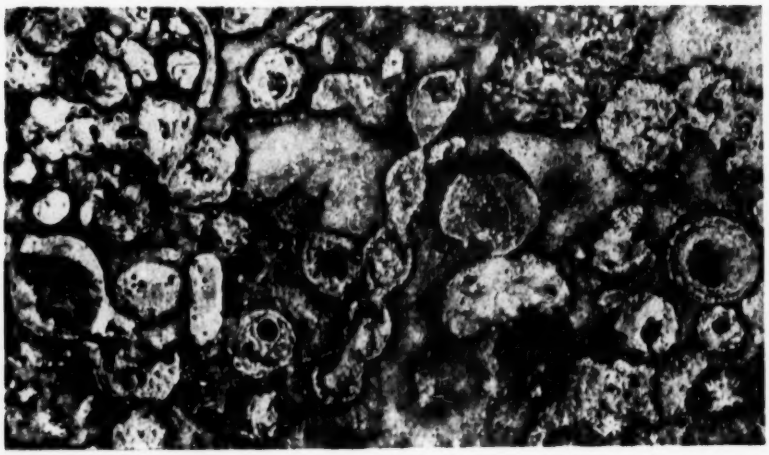
Johnson, Texas Permian calcareous Algae



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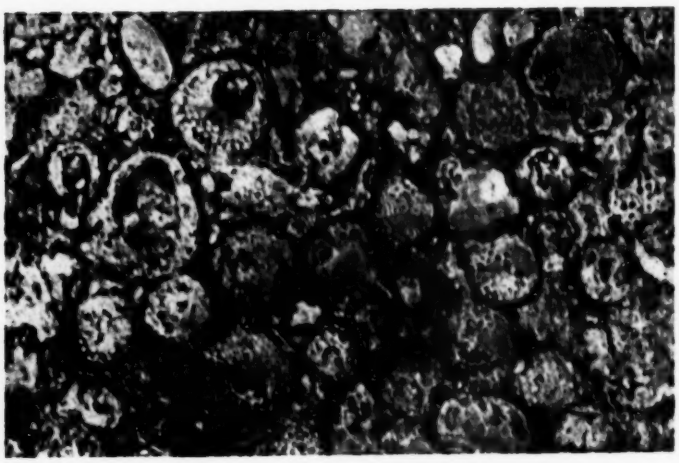

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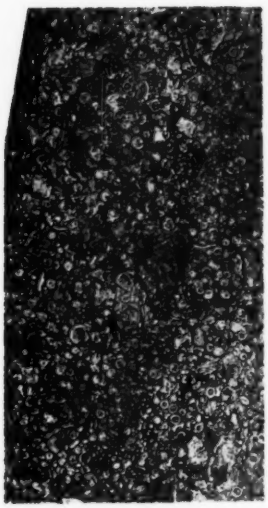

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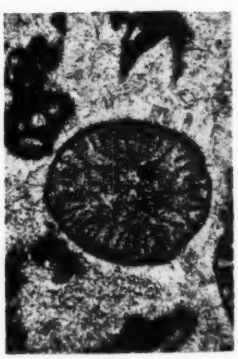

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Johnson, Texas Permian calcareous Algae

SOLENOPORA TEXANA Johnson, n. sp.
Plate 6, figures 4 and 5

Thallus encrusting to nodular; 0.5 to 6.2 mm. thick. Composed of long, slender, tubular cells having a diameter of 0.006 to 0.013 mm. and forming irregular growth zones. No cross partitions visible. Cells rather widely spaced with thick coating of algal dust between. No suggestions of sporangia.

Type specimen.—Slides 1015 and 1116, Johnson collection, Colorado School of Mines.

Remarks.—Specimens of this species occur on several of the slides studied. Some appear to form nodular or hemispherical masses, others encrust bryozoan shreds and other foreign material. In general appearance of the tissue, it somewhat suggests an encrusting *Lithothamnium* but lacks the well defined cross partitions of the latter. However, it resembles a *Lithothamnium* more closely than any other Paleozoic *Solenopora* known to the writer.

Pia (1940, p. 3) mentions a *Solenopora* spec. ind. which may belong to this species. It has tubes of the same diameter which definitely lack transverse partitions.

Class CHLOROPHYTA
Order SIPHONOCLADALES
Family DASYCLADACEAE

Fragments of Dasycladaceae are common in the Apache Mountain limestones. Several genera are present, but *Mizzia* is the only one that occurs abundantly. Locally *Mizzia* fragments are so numerous that they form thick limestone masses. Specimens of these *Mizzia* are shown in plate 7.

Genus MIZZIA Schubert 1907
Plate 7

Thallus composed of several spherical or elongated members growing on a common stem, suggesting a string of beads. These members usually break apart at the narrow connecting necks. Central stem relatively thick, swelling in the center of each member and narrowing at the necks. The pores representing the primary branches unbranched, increasing in size toward the exterior and arranged in concentric rows around the stem. Sporangia unknown; possibly they developed within the central stalk. This genus has been discussed in detail by Johnson and Dorr (1942).

MIZZIA VELEBITANA Schubert
Plate 7, figures 1–4

Mizzia SCHUBERT, 1907, K. k. geol. Reichsanstalt, Verhandl. Wien, no. 8, p. 212.
Mizzia velebitana SCHUBERT, 1908, K. k. Geol. Reichsanstalt, Wien, Jahrbuch Band 58, Heft 2, p. 382, pl. 16, figs. 8–12.
Mizzia velebitana KARPINSKI, 1908, Russ. Min. Gesell. Verh., ser. 2, vol. 46, p. 262, pl. 3, figs. 6–9.
Mizzia cf. *velebitana* KARPINSKY, idem, p. 266, pl. 3, figs. 1, 3, 4, 10–13.
Guadalupia? sp. GIRTY, 1908, U. S. Geol. Survey Prof. Paper 58, p. 85, pl. 5, figs. 7–11.
Mizzia velebitana PIA, 1920, Zool. botan. Gesell., Wien, Abh., Band 11, Heft 2, p. 19, figs. 12–23, pl. 1.
Mizzia velebitana PIA, 1937, 2me Cong. Strat. Carbonif. Heerlen 1935, Compte rendu, p. 765, pl. 9, fig. 3.
Mizzia velebitana PIA, 1940, Akad. Wiss. Wien, Math.-natur. Kl., Sitzungsber.
Mizzia velebitana JOHNSON and DORR, 1942, Jour. Paleontology, vol. 16, no. 1, pp. 71–73, pl. 9, figs. 1–3; pl. 10, figs. 2, 3, 5; pl. 11, figs. 1–2.
Mizzia velebitana JOHNSON, 1942, Geol. Soc. America Bull., vol. 53, pp. 203–205, pl. 2; figs. 1, 2, 4; pl. 3, figs. 1, 2, 3.

Description.—Thallus composed of spherical or pyriform members arranged along a central stem. Wall of individual members traversed by branches which increase in size as they approach the outer surface

EXPLANATION OF PLATE 7
Dasycladaceae

FIGS. *1–3*—*Mizzia velebitana* Schubert, ×7. Details from a weathered hand specimen. Figure *1* shows a series of five attached segments; figure *3* shows two attached segments. (p. 23)
4—*Mizzia velebitana*, showing a typical cross section somewhat above the equatorial region. ×30. (p. 23)
5—*Mizzia minuta* Johnson and Dorr, showing surface of a weathered hand specimen with many segments. ×4. (p. 24)
6—*Anthracoporella* sp., a cross section. ×40. (p. 24)
7—*Anthracoporella* sp., cross section. ×25. (p. 24)

of the member. Number of pores in equatorial region 20 to 25.

Remarks.—The specimens from the Apache Mountain region closely resemble the typical European species but differ in several respects: (1) The members are often less symmetrical and more pyriform; (2) the neck or constricted area between members is often much longer and more slender; (3) the branches appear to terminate at the outer surface of the member in small rounded protuberances each containing a small circular opening at the summit instead of large open "pores" as described by Pia. This may be a matter of preservation. See Johnson and Dorr (1942, pp. 72–73).

TABLE 2.—DIMENSIONS (IN MM.) *M. velebitana*

Outer diameter	Inner diameter	Thickness calcareous walls	Diameter of pores	Distance between centers of rows of branches (verticillatae)
1.225	0.875	0.175	4.078	
1.7500	1.480	0.1225		
1.225	0.750	0.350	4.062	
1.750	1.225	0.630		
1.663	1.225			
1.820	1.295	0.700	4.084	1.750
1.838	1.050	0.260		1.880

TABLE 3.—DIMENSIONS (IN MM.) *M. minuta*

Outer diameter	Inner diameter	Thickness of walls	Diameter of branches (pores)	Diameter main stem	Distance between rows of branches
0.875	0.437	0.175		0.227	0.157
0.900	0.350	0.210	0.887	0.175	
0.612	0.315			0.175	
0.875	0.437	0.175	0.700	0.385	0.140
0.962	0.350	0.182	0.875		

MIZZIA MINUTA Johnson and Dorr
Plate 10, figure 4

Johnson and Dorr, Jour. Paleontology, vol. 16, 1942, no. 1, p. 73.

Thallus unbranched, consisting of a number of spherical or ellipsoidal members developing along a single axial cavity. Individual members usually symmetrical, or nearly so. Branches undivided, increasing in size outward from the axial cavity.

Number of branches in the equatorial region ranges from 13 to 16. In upper portion of the member the branches are almost parallel to the main axis of the plant; in the equatorial region they are nearly perpendicular to the axis, while the basal branches are only slightly inclined toward the axis in a direction opposite from those at the top.

Walls from 0.135 to 0.265 mm. thick.

A number of specimens were found showing a series of connected members.

Remarks.—This species closely resembles *Mizzia velebitana* except it is smaller in size and has a smaller number of pores in the equatorial region. It is the most abundant species in the Apache Mountain collections.

Genus ANTHRACOPORELLA Pia 1920
ANTHRACOPORELLA sp.
Plate 7, figures 6 and 7

Two slides studied contain small cross sections with a structure very similar to Pia's illustration of *Anthracoporella specta-*

bilis. They show numerous closely packed, long, bifurcating branches, but a very poorly outlined central stem. Dimensions are: diameter, 0.858 mm.; diameter of branches, 0.065 to 0.079 mm.; diameter of central stem, about 0.250 mm. Number of branches, about 30.

Figured specimens.—Slides 886 and 1077, Johnson collection, Colorado School of Mines.

Remarks.—Representatives of this genus have been reported from the Pennsylvanian and Permian of several European localities. This is believed to be the first suggestion of an American occurrence. Unfortunately, the material is too limited to justify more than a mere mention. It is hoped that later workers will be stimulated to make larger collections which will yield more abundant specimens.

Genus DIPLOPORA Schafhäutl
DIPLOPORA AMERICANA
Johnson, n. sp.
Plate 8, figure 5

Thallus long, club-shaped; central stem of moderate thickness; primary branches in bundles of four, regularly arranged in evenly spaced horizontal rows. Branches appear to be thickest near the base and tapering gently to pointed end. Sporangia not observed.

Dimensions.—Thallus, 15.85 mm. long, maximum width 3.08 mm.; average thickness calcified zone, 0.70 mm.; diameter branches (pores), 0.125 to 0.138 mm. near base.

Type.—Slide 1084, Johnson collection, Colorado School of Mines.

Remarks.—This species was represented by one approximately complete specimen (Pl. 8, fig. 5) and several fragments. It shows plainly the basic features of the genus. The species suggests *Diplopora clavaeformis* Pia, but differs from it by having a longer, more gently tapering thallus and more closely spaced branches.

DIPLOPORA? sp.?
Plate 9, figure 5

One slide shows the outline of a form which is too badly recrystallized to give structural details. It is club-shaped with a length (of the fragment) of 2.86 mm. It probably belongs to the genus *Diplopora*, but differs from *D. americana* in having a much more rapidly expanding thallus.

Figured specimen.—Slide 468, Johnson collection, Colorado School of Mines.

TABLE 4.—MEASUREMENTS (IN MM.) *G. symetrica*

Outside dimensions of fragment	Thickness calcification	Diameter central stem	Diameter branches	Distance between whorls
1.7 ×1.87	0.44—0.275	0.90–1.25	0.092–1.123	
1.21× .94	0.24—0.37	0.50–0.40	0.075–0.083	
			0.066–0.110	0.040–0.061
3.08×1.76	0.22—0.29	0.90–1.10	0.046–0.077	0.048–0.062
3.50×2.45	0.37—0.48	1.20–1.70	0.066–0.081	0.046–0.064
2.09×0.72	0.11—0.10	0.35–0.50	0.048–0.0590	
2.90×2.08	0.38—0.44		0.750	

Genus GYROPORELLA Gumbel emend. Benecke
GYROPORELLA SYMETRICA
Johnson, n. sp.
Plate 8, figure 7; Plate 10, figures 1–5

Thallus long, club-shaped, circular to oval in cross section. Closely spaced horizontal rows (whorls) of branches which are shaped like a drumstick (i.e., a slender shape with a ball-like expansion at the end). Central stem club-shaped and relatively wide in proportion to the entire thallus. Sporangia probably spherical and developing at the ends of some of the primary branches in the upper part of the thallus.

Type specimens.—Slides 1108 and 1117. Other figured specimens: Slides 334, 1093, 1091, Johnson collection, Colorado School of Mines.

Remarks.—This form resembles *Gyroporella maxima* Pia in general appearance but differs in dimensions of the various parts and in having the branches and whorls more regularly and symmetrically spaced.

This is believed to be the first reported occurrence of this genus in America and the first record of it in Permian strata.

Genus MACROPORELLA Pia
MACROPORELLA APACHENA
Johnson, n. sp.
Plate 8, figures 1–4

Thallus cylindrical to barrel-shaped with relatively large central stem. Branches arranged in closely spaced whorls, 20 to 38 branches in a whorl depending on whether at middle or near end. Branches inclined to central stem, expanding gradually from base to end.

Type specimen.—Slide 1103, Johnson collection, Colorado School of Mines.

Remarks.—This species closely resembles *Macroporella verticillata* described by Pia from the Guadalupe Mountains of New Mexico, but differs in larger size of thallus and in having larger and more widely spaced branches. Unfortunately, Pia gives no illustrations. It closely resembles the illustration of *M. beneckei* Salomon from the Triassic of Albania and Greece, but has larger branches which are more regularly arranged in more closely spaced whorls.

MACROPORELLA CALCIPORA Pia

PIA, J., 1940, pp. 2–3. No illustrations.

Pia describes it approximately as follows: Thallus small, stem slender, branches in whorls forming a broad smooth calcified layer. Cross section somewhat suggests the genus *Rhabdoporella* Stolley.

One of the slides from the Apache Mountains contains several fragments which fit Pia's descriptions and measurements.

MACROPORELLA sp.
Plate 8, figure 6

One slide studied contains a single section of a large *Macroporella* with thick central stem. Branches large and wide, arranged in regular horizontal whorls. It has a larger central stem and wider branches than any of the other species of *Macroporella* studied. However, the material available is considered too meager to warrant description and naming.

Figured specimen.—Slide 986, Johnson collection, Colorado School of Mines.

TABLE 5.—DIMENSIONS (IN MM.) *M. apachena*

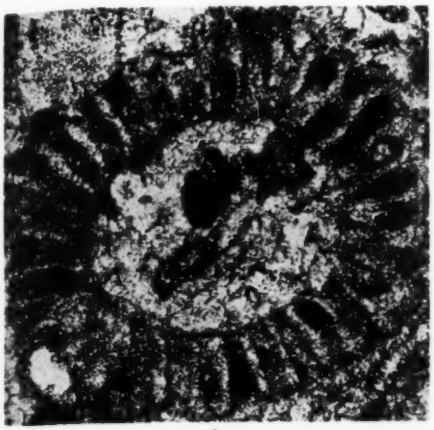
Diameter thallus	Diameter central stem	Thickness calcification	Diameter of branches		Distance between whorls
			Top	Base	
1.435	0.726	0.37 –0.460	.086–.095	.035–.040	.059–.064
0.080	0.362	0.238–0.242	.070–.084	.044–.059	.037–.044
1.320	0.726	0.286–0.330	.057–.079	0.35–.044	.035–.042

Order SIPHONALES
Family CODIACEAE
Genus GYMNOCODIUM Pia 1919

This genus is characterized by having a thallus consisting of numerous well defined cylindrical elements in a fine pulpy mass, covered by a skin. These are preserved as

EXPLANATION OF PLATE 8
Dasycladaceae

FIG. *1*—*Macroporella apachena* Johnson, n. sp., slightly oblique section. ×40. (p. 26)
2—Same. Portion of a segment approximately parallel to the long axis. ×40.
3—Same. A badly worn fragment nearly parallel to the long axis. ×25.
4—Same. A slightly oblique cross section. ×40.
5—*Diplopora americana* Johnson, n. sp., a longitudinal section ×10. (p. 25)
6—*Macroporella* sp., an oblique section. ×25. (p. 26)
7—*Gyroporella symetrica* Johnson, n. sp. A slightly oblique cross section. ×15. (p. 25)



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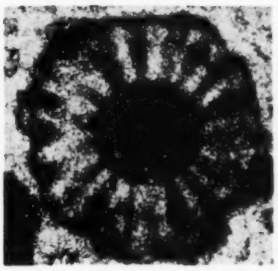

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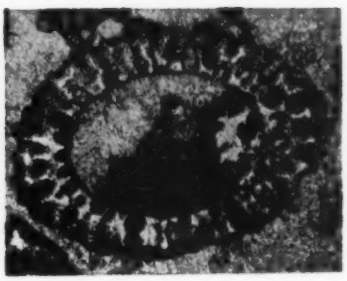

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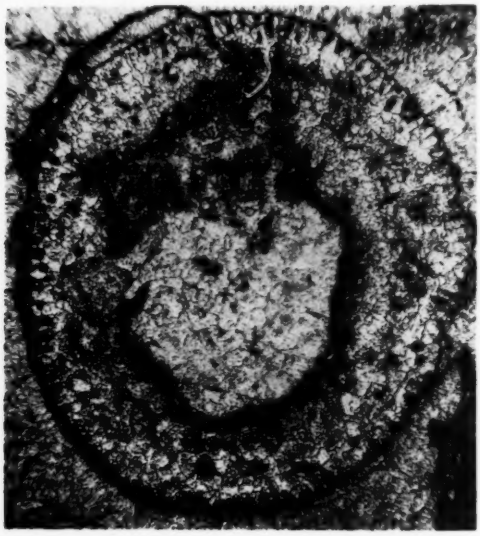
Johnson, Texas Permian calcareous Algae



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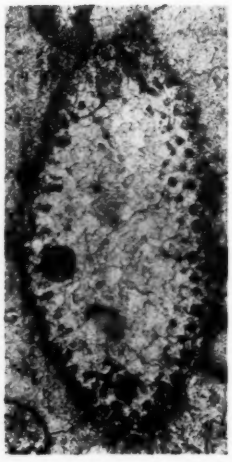

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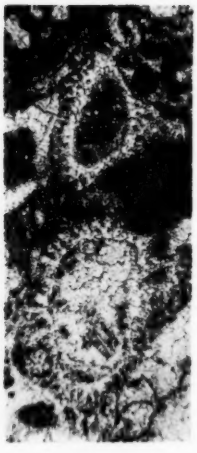

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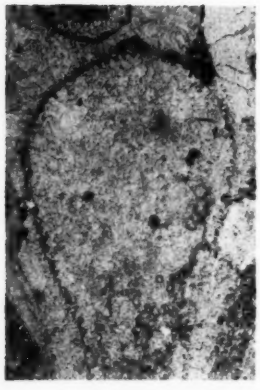

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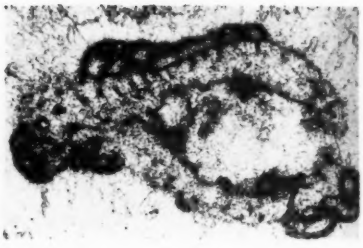

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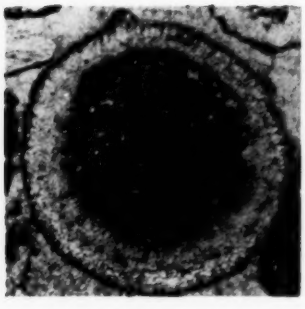

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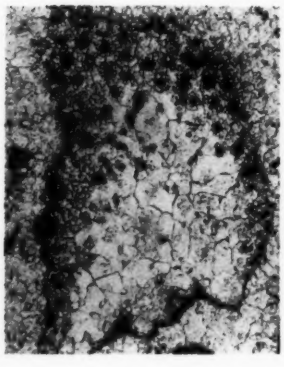

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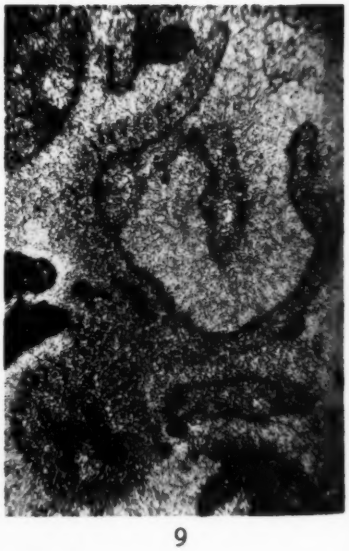

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Johnson, Texas Permian calcareous Algae

dark tubular molds in a lighter calcareous mass. Usually only the outer portions are calcified, although the amount of calcification varies greatly. As a result the inner portions of the thallus are seldom preserved. Sporangia spherical to oval, imbedded in outer portions of the thallus.

Thalles cylindrical, oval, club-shaped; sometimes branching. Some show a more or less regular pinching and swelling. The structure strongly suggests modern Codiaceae, especially *Boueina* and *Halimeda*.

Pia named a number of species from the Permian of the Balkan region of Europe. He gave good illustrations of some of them (1937, pls. 11, 12, 13), but his descriptions are vague with few or no measurements given. It is difficult to make accurate comparisons with his species. They were divided into species on the basis of shape and size of pore. The present writer uses the same system.

GYMNOCODIUM TEXANUM
Johnson, n. sp.
Plate 9, figures 6 and 8

Thallus cylindrical, pinching and swelling. Growing tips pointed. Surface covered with closely spaced round pores, which are outlets of inner tubes. Dimensions of several of the better preserved specimens are tabulated below.

TABLE 6.—DIMENSIONS (IN MM.) *G. texanum*

Slide number	Size fragment		Diameter pores near outer rim	Diameter pores on outer surface
	Outside	Inside		
334	0.55×0.88	0.33×0.72	0.020 to 0.290	
334	0.44×0.68	0.29×0.49	0.020 to 0.024	
826	0.66×1.10	0.36×0.66	0.015 to 0.026	
826	1.98×1.32	1.06×0.66		0.033 to 0.040
732	0.66×1.10			0.026 to 0.029

It should be noted that the difference of inner and outside dimensions of fragment merely means the thickness of calcification. Sporangia not present.

Type specimens.—Slides 826, 732, 334, Johnson collection, Colorado School of Mines.

Remarks.—This is the most common species in the collection. It is close to *Gymnocodium tenellum* Pia in general appearance, but has much smaller pores.

EXPLANATION OF PLATE 9
Codiaceae and Dasycladaceae

FIG. 1—*Gymnocodium* cf. *fragile* Pia. A fairly well preserved specimen with a thick calcified crust. ×25. (p. 28)

2—*Gymnocodium* sp. A section considerably nearer the outer edge than the center. ×40. (p. 28)

3—*Gymnocodium forcepinum* Johnson, n. sp. A nearly longitudinal section of a poorly preserved specimen with a thin calcified crust. ×15. (p. 28)

4—*Gymnocodium* sp.? Oblique sections of small fragments. ×25. (p. 28)

5—*Diplopora* sp.? Longitudinal section of a poorly preserved badly recrystallized specimen. ×30. (p. 25)

6—*Gymnocodium texanum* Johnson, n. sp. A nearly longitudinal section. ×40. (p. 27)

7—*Gymnocodium* cf. *fragile*. A fairly typical specimen with a medium calcified crust. ×15. (p. 28)

8—*Gymnocodium texanum* Johnson, n. sp. Oblique section. ×40. (p. 27)

9—*Gymnocodium forcepinum* Johnson, n. sp. The type specimen—a slightly oblique section. ×25. (p. 28)

GYMNOCODIUM FORCEPINUM
Johnson, n. sp.
Plate 9, figures 3 and 9

Thallus cylindrical, pinching and swelling, growing tips open, shaped like the end of a pair of tongs or forceps. Surface covered with round pores arranged in fairly regular rows. Sporangia oval.

Type specimens.—Slides 826 and 1085, Johnson collection, Colorado School of Mines.

Remarks.—In general appearance and dimensions this form closely resembles Pia's illustration of *Gymnocodium fragile* (Pia, 1937, pl. 12, fig. 2) and the very vague description given by him.

TABLE 7.—DIMENSIONS (IN MM.) *G. forcepinum*

Slide number	Size fragment		Thickness calcification	Pores diameter	Sporangia
	Outside (width)	Length			
826	.660–0.132	5.16	0.180–0.660	0.030–0.040	.154×.205
826	.825–1.760	4.84	0.220–0.330	0.032–0.038	none
1085	.720–1.540	2.64	0.030–0.770	0.026–0.037	.060–.075 × .080–.130
1085	.660–1.320	5.94	0.155–0.480	poorly defined	none

GYMNOCODIUM sp.?
Plate 9, figures 2 and 4

In addition to the species already described, a number of irregular fragments were observed. They probably do not all belong to one species. The material is too meager and mostly too poorly preserved to warrant description. A few of the larger are illustrated and their dimensions are listed below.

GYMNOCODIUM cf. FRAGILE
Plate 9, figures 1 and 7

Thallus cylindrical, apparently pinching and swelling only slightly. Surface covered by closely spaced pores; growing tip rounded, only slightly pointed. No sporangia observed.

Figured specimens.—Slides 1094 and 1164, Johnson collection, Colorado School of Mines.

Remarks.—This species is represented by five specimens in slides studied. It differs appreciably in shape and dimensions from any previously described species known to the writer.

Class CYANOPHYTA (possibly CHLOROPHYTA)
Family POROSTROMA
Genus GIRVANELLA Nicholson and Etheridge 1880
GIRVANELLA cf. MAGNA Johnson
Plate 10, figures 6 and 7

Coarse twisting tubes with well defined walls, which coat or fill fragments of fossils

EXPLANATION OF PLATE 10

FIGS. *1–5—Gyroporella symetrica* Johnson, n. sp. (p. 25)
1—Slightly oblique section of a fragment. ×30.
2—A longitudinal section, showing closely spaced regular rows of branches. ×15.
3—A slightly oblique longitudinal section. ×15.
4—A slightly oblique cross section. ×25.
5—A near-surface section of a fragment showing regular spacing of branches. ×25.
6, 7—Girvanella cf. *magna* Johnson. (p. 28)
6—Portion of an irregular nodular colony. ×25.
7—Girvanella tubes inside a badly worn fragment of a dasycladacean alga. ×25.
8—Ortonella gracilis n. sp. Portion of a colony. ×25. (p. 29)
9—Perforating algal threads which have penetrated a fusulinid foraminifer, partly destroying the shell and filling the outer chambers. ×50. (p. 30)

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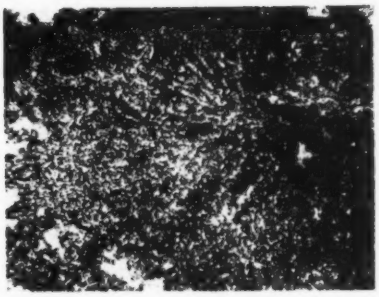

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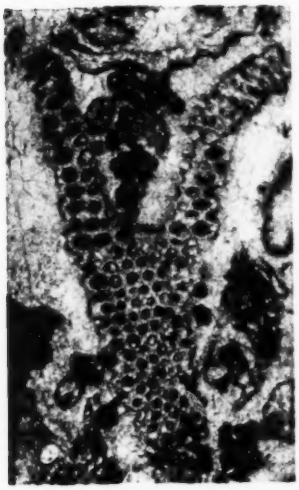

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Johnson, Texas Permian calcareous Algae

or more rarely occur loose in the groundmass. Tube diameter 0.035 to 0.041 mm. Thickness of walls 0.0066 to 0.0088 mm.

Figured specimens.—Slides 1014 and 1072, Johnson collection, Colorado School of Mines.

Remarks.—In appearance, habit, and dimensions this species very closely resembles *Girvanella magna* described by Johnson (1946, p. 1101) from the Middle Pennsylvanian Lenapah limestone of Kansas. The tubes average slightly smaller and have slightly thinner walls, but they overlap the size range of the former.

TABLE 8.—DIMENSIONS (IN MM.) *G.* cf. *fragile*

Slide number	Size outside	Thickness calcification	Pore diameter	Sporangia
468	2.86×2.64	.627–1.012	0.055– .070	Absent
470	4.29×3.70	.847–1.122	0.037–0.055	Absent
1039	3.52×3.41	.385–0.595	0.040–0.053	Absent
1094	2.50×2.20	.385–0.490	0.030–0.048	Absent
1095	2.97×2.77	.275–0.450	0.033–0.042	Absent

TABLE 9.—DIMENSIONS (IN MM.) *G.* sp.

Slide number	Size fragment	Thickness calcification	Pore diameter	Sporangia
469	1.87×2.53	0.176–0.385	0.028–0.053	Absent
1096 (1)	2.21×3.30	0.165–0.462	0.037–0.051	Absent
1096 (2)	2.53×1.54	0.275–1.100	0.037–0.048	Absent
1105	2.20×3.52	0.385–0.660	0.048–0.059	Absent

Genus ORTONELLA Garwood 1913

ORTONELLA GRACILIS
Johnson, n. sp.
Plate 10, figure 8

Plant consists of an irregular cushion of branching threads which radiate from the center of the base. Plants form masses up to 4 mm. long, average about 2.5 mm. Threads long and slender, 0.022 to 0.026 mm. across, bifurcating at an angle of 35° to 40°.

Type specimen.—Slide 1024, Johnson collection, Colorado School of Mines.

Remarks.—This genus was abundant and widespread during Mississippian time, and representatives have been noted in the Pennsylvanian but appear to be rare in the Permian. *Ortonella gracilis* closely resembles *O. coloradoensis* Johnson described from the Mississippian of central Colorado but differs in having slightly smaller threads and a smaller angle of branching.

ORTONELLA sp.?

In addition to *Ortonella gracilis*, a number of slides show fragments of masses of branching algae which probably belong to this genus. Unfortunately, they are too poorly preserved to merit description or naming.

Class CYANOPHYTA
Family SPONGIOSTROMA

Pia erected this family to include the great number of fossils which form spongy colonies of molds of algal threads. The colonies of various species and genera included in this group show a variety of shapes. Frequently they form "biscuits," or rounded cabbage-like masses. Some form irregular streamers or coatings. The cellular structure is seldom preserved; usually the most that can be seen are vague outlines of fine threads. In general they make very unsatisfactory fossils.

Numerous examples of algae belonging to this group were encountered in the collection studied. However, no attempt is made to describe them owing to limited time available and to the fact that they have much less value in correlation than the higher types of algae which show definite microstructure.

Perforating Algae
Plate 10, figure 9

Numerous examples of perforating algae were observed in this study. They are present in most of the specimens examined. Usually, they consist of very fine algal threads (average diameter 0.0025 to 0.0038 mm.), which coat and penetrate fossils and fossil fragments, especially Foraminifera, Bryozoa, and echinoderms. Many fusulinids were observed partially or completely filled with them (pl. 10, fig. 9). Where abundant, they appear to alter and disintegrate the test, shell, or echinoderm plate.

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JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 1, PP. 31–34, 8 TEXT FIGURES, JANUARY 1951

TWO NEW GENERA OF FORAMINIFERA FROM RECENT DEPOSITS IN LOUISIANA

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INTRODUCTION

THE present study has resulted from a nomenclatural need in conjunction with a research problem on the ecology of the Mississippi River delta. The two genera of Foraminifera described as new were present in several littoral samples examined by the writer. One genus (*Bisaccium*) apparently has never been recorded. The other (*Arenoparrella*) has been reported from the Gulf Coast by Kornfeld (1931) as *Trochammina* which is an incorrect generic assignment, sensu strictu. The names introduced will facilitate the current environmental investigation, especially the nomenclatural difficulties in the brackish water assemblage of which these two genera are important constituents.

The genera and species described herein came from a sample of beach sand collected on the east side of South West Pass, approximately one mile south of Burrwood, Louisiana. The genus *Bisaccium* is based upon 45 specimens recovered from the soap-floated concentrate, the genus *Arenoparrella* on 21 specimens. Additional specimens of both genera have been recorded by the writer from Redfish Bay which lies between South Pass and North East Pass, and from Grand Isle which lies between 30 and 40 miles northwest of the mouths of the passes of the Mississippi River.

The writer is indebted to Dr. H. N. Fisk, Chief Research Geologist, Humble Oil Company, Houston, Texas, for the sample from which the new genera have been described and for his encouragement in the current environmental study.

Family TROCHAMMINIDAE
Genus ARENOPARRELLA
Andersen, n. gen.

Genotype *Trochammina inflata* (Montagu) var. *mexicana* Kornfeld.

Test free, trochoid, umbilical area closed and depressed, dorsal side convex; wall finely arenaceous; aperture a slit-like opening with long axis oriented approximately parallel to the plane of coiling, either open at the base or separated from the preceding volution by a thin everted lip.

Remarks.—The major difference between this genus and the closely related *Trochammina* lies in the shape and position of the aperture. *Trochammina* encompasses those trochiform tests in which the aperture is a slit or arched opening at the ventral inner margin of the last formed chamber; *Arenoparrella* those trochiform tests in which the aperture is an elongate slit roughly parallel to the periphery.

ARENOPARRELLA MEXICANA
(Kornfeld)
Figures 1a-c

Trochammina inflata (Montagu) var. *mexicana* KORNFELD, 1931, Contr. Stanford Univ. Geol. Dept., vol. 1, p. 86, pl. 13, figs. 5a–c.

Test trochoid, dorsal side moderately convex, ventral side with a depressed, closed umbilicus; periphery bluntly acute, lobulate in adult specimens. Chambers typically five to each whorl, slightly inflated on dorsal side, ventral side with pronounced inflation of chambers near the umbilicus; sutures distinct, slightly curved on dorsal side, radial and straight on ventral side. The aperture is a curved, almost angular slit in the apertural face of the last chamber, the inner portion of the curve extending from the periphery ventrally at an angle of 30 to 40 degrees with the plane of coiling, the outer portion of the curve oriented almost parallel to the plane of coiling. The aperture is surrounded by a thin delicate everted lip which in some specimens continues across the base of the aperture thus separating the aperture from the preceding volution. A chitin proloculum is visible at the apex of the dorsal spire; the adult portion of the

test is composed of approximately equal amounts of yellowish-brown cement and fine grained arenaceous material.

Maximum diameter of figured specimen 0.46 mm; maximum thickness 0.18 mm.

Remarks.—The shape and position of the aperture typical of the specimens in the writer's collection is dissimilar to that of the holotype of *A. mexicana* described and figured by Kornfeld (1931). The holotype may have the type aperture illustrated but this aperture is not typical of the species. This became evident after the writer examined some of the samples collected off the coast of Louisiana by Kornfeld in 1929 and 1930 that had been presented to Dr. H. V. Howe, Director, School of Geology, Louisiana State University. Dr. Howe had not received a cut of the Timbalier Island sample from which the holotype of *A. mexicana* was described, but does have in his collection a sample from the south side of Calumet Island in Timbalier Bay (M.M. Kornfeld Sample No. 33 collected April 8, 1929). This sample provided 15 specimens which for all practical purposes can be considered topotypes of *A. mexicana*. From this suite of 15 specimens it is evident that the typical aperture in *A. mexicana* is a curved to distinctly angular slit-like opening rather than " . . . a small arched slit" as designated in Kornfeld's description or the straight slit-like opening shown in his figured holotype. It is also evident that the specimen figured herein with aperture closed at the base can be found on many specimens but is not a persistent characteristic of the species.

Distribution.—*A. mexicana* (Kornfeld) has been found by the writer in four localities along the Louisiana coast: 1) Redfish Bay located between South Pass and South East Pass, 2) South West Pass, 3) Grand Isle located northwest of the passes at the mouth of the Mississippi River, and 4) Calumet Island in Timbalier Bay (M. M. Kornfeld Sample No. 33). Kornfeld (1931) reports having found the species as far east as Chandeleur Island and as far west as Calcasieu Pass, south of Lake Charles, Louisiana.

Repository.—Hypotype No. 4200 is deposited with the H. V. Howe Collection, School of Geology, Louisiana State University.

Family NONIONIDAE

Genus BISACCIUM Andersen, n. gen.

Genotype *Bisaccium imbricatum* Andersen, n. sp.

Test free, calcareous perforate, planispiral, bilaterally symmetrical; chambers distinct, consisting of a primary series of closely coiled chambers and a supplementary series in which each individual supplementary chamber covers the inner portion of the last formed chamber, a portion of each umbilicus and the last formed suture on both sides of the test; primary chambers inflated in the anterior portion, thinning posteriorly with sides becoming parallel at point of juncture with previously formed chamber; sutures in the primary chambers depressed.

All exposed apertures are openings left between the supplementary and primary chambers, the most apparent and important of which are two hip-pocket-like openings in the median, distal portion of the apertural face, and the openings near the peripheral margin of each suture where the supplementary chamber suture-line extension terminates. The true aperture in the primary chamber, concealed by the supplementary chamber, lies at the base of the chamber in the median line.

Remarks.—The genus *Bisaccium* can not be placed satisfactorily in any family. It has been referred to the Nonionidae since the primary chambers, at least, conform with the basic pattern of the family. It might be desirable when additional species of this genus are reported to establish a new family to accommodate those planispiral forms with alternating primary and supplementary chambers. This new family could include the genus *Bisaccium* and possibly the genera *Cushmanella* and *Astrononion*.

BISACCIUM IMBRICATUM Andersen, n. sp.

Figures 2a–e

Test free, planispiral, bilaterally symmetrical; periphery rounded with last three or four chambers asymmetrically lobulate; chambers distinct, consisting of a primary series of seven or eight closely coiled chambers which increase gradually in size as added and a supplementary series in which each individual supplementary chamber

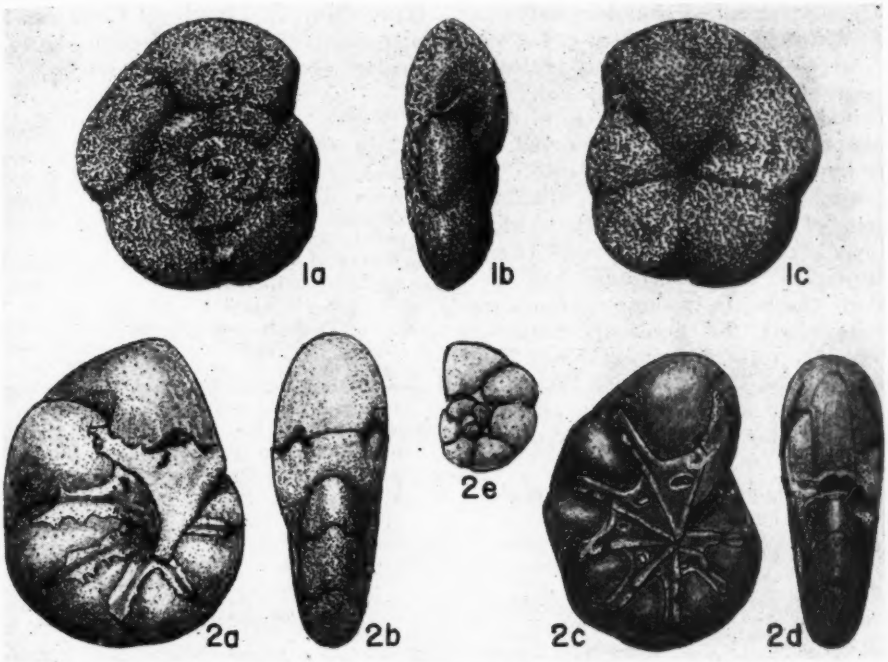

FIG. 1—*Arenoparrella mexicana* (Kornfeld), Hypotype, H. V. Howe Coll. No. 4200, ×80; *a*, dorsa view; *b*, peripheral view; *c*, ventral view.
FIG. 2—*Bisaccium imbricatum* Andersen, n. sp., ×80; *a*, side view and *b*, peripheral view of holotype H. V. Howe Coll. No. 4201; *c*, side view and *d*, peripheral view of paratype H. V. Howe Coll. No. 4202; *e*, side view of chitinous residue from paratype H. V. Howe Coll. No. 4203.

covers the inner one third to one-half of the last formed chamber, a portion of each umbilicus and the last formed suture on both sides of the test; primary chambers inflated in the anterior portion, thinning posteriorly with sides becoming parallel at point of juncture with previously formed chamber; sutures in primary chambers depressed except over periphery, curved and forming a lobe on the periphery. The true aperture in the primary chamber, invisible except in broken specimens, lies at the base of the chamber in the median line and is concealed by the supplementary chamber.

The supplementary chambers have triangular-shaped projections which extend into the umbilical region, and are imbricate in that each successive projection overlaps the previous one. When the projection and amount of overlap is uniform, a stellate pattern is formed on the side of the test.

The outer portion of the supplementary chamber is securely welded to the primary chamber except for: 1) two hip-pocket-like openings in the median, distal portion of the apertural face, 2) a variable number of small cribrate openings typically along the posterior margin of the extension which covers the sutures, and 3) an opening near the peripheral margin of each suture where the supplementary chamber suture-line extension terminates. All the above openings apparently served as apertures throughout the life of the individual. Even the pocket-like opening which is eventually concealed by subsequent supplementary chambers remains open in the depressed suture line. A small elliptical or circular opening (aperture ?) occurs within the supplementary chamber on both sides of the test.

Three specimens treated with dilute acid revealed a chitinous lining in the umbilicus of the primary chambers. The insoluble chitinous residue, consisting of a proloculum and eight to nine planispirally coiled chambers, ranged from 0.15 to 0.22 mm. in diame-

ter. The supplementary chambers were completely dissolved.

The test is calcareous, finely perforate. The wall of the test is so thin and fragile that specimens are rarely found with the last supplementary chamber preserved.

Maximum diameter of figured holotype is 0.52 mm; thickness 0.20 mm. Maximum diameter of figured paratype, H. V. Howe Coll. No. 4202, 0.50 mm; thickness 0.18 mm.

Distribution.—*B. imbricatum* has been found by the writer in samples from three localities along the Louisiana coast: 1) Redfish Bay located between South Pass and South East Pass, 2) South West Pass, and 3) Grand Isle located northwest of the passes at the mouth of the Mississippi River.

Repository.—Holotype No. 4201 and paratypes Nos. 4202 and 4203 are deposited with H. V. Howe Collection, School of Geology, Louisiana State University.

MANUSCRIPT RECEIVED FEBRUARY 11, 1950.

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FORAMINIFERA AND STRATIGRAPHY OF THE FRONTIER FORMATION (UPPER CRETACEOUS), SOUTHERN MONTANA

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ABSTRACT—The Frontier formation of southern Montana is divided into seven stratigraphic units. The stratigraphic relationships and the environments of deposition of the different units are discussed. The faunas obtained from the units of the Frontier formation of southern Montana are compared with faunas of the Frontier formation and the Carlile shale of other areas. It is suggested that the term "Carlile shale" be discontinued as a rock name in southern Montana and that the Frontier formation be redefined to include all rocks between the top of the Mowry shale and the base of the Niobrara formation.

A new foraminiferal fauna is described from the upper part of the Frontier formation of southern Montana. Thirty-four species, twenty-seven of which are new, are described and referred to seventeen genera. This fauna has a preponderance of members of the families Heterohelicidae, Globigerinidae, and Lagenidae, and, in this respect, is typical of Upper Cretaceous foraminiferal assemblages. It differs from other American Upper Cretaceous foraminiferal faunas by the presence of a characteristic group of species of the genus *Marginulinopsis*.

INTRODUCTION

THIS paper presents the results of some investigations conducted in rocks of Turonian age (Upper Cretaceous) in the Frontier formation of south-central Montana. The object of the field work was to delineate the stratigraphic and areal extent of the *Vascoceras* fauna (Reeside, 1923) and to obtain additional information concerning the faunal and stratigraphic characteristics of the Frontier formation. Shale samples collected at identifiable horizons during the 1947 field season yielded the hitherto undescribed foraminiferal fauna which makes up the major portion of this paper.

The Frontier section (Thom et al., 1935) east of the Soap Creek oil field was used as the section of reference (fig. 1) .The rocks were examined along the strike to the southeast toward the Montana-Wyoming state line and to the northwest almost to Billings, Montana. All of the sections and localities visited, except one, are within the Crow Indian Reservation, Big Horn and Yellowstone Counties, Montana. The one exception is located approximately one mile from the reservation in the vicinity of Billings, Montana. Four sections were measured during the course of the field work. These are at widely separated localities.

I wish to express my sincere thanks to W. T. Thom, Jr., for suggesting the problem and for many valuable ideas during the course of the field work. I am indebted to M. L. Thompson for constructive criticism of the foraminiferal and stratigraphic studies and for reviewing the manuscript. Some of the problems have also been discussed with H. D. Thomas, J. B. Reeside, Jr., L. M. Cline, S. K. Fox, and Helen Jeanne Plummer. The considerations of these persons are greatly appreciated. I wish to thank also Mr. and Mrs. Robert S. Kennedy, my hosts for part of the 1947 field season.

STRATIGRAPHY

General

The rocks discussed in this paper belong to the Colorado group of the Upper Cretaceous. In ascending order the Thermopolis shale, Mowry shale, Frontier formation, and Niobrara shale make up the Colorado group (fig. 2). The rocks of the group consist primarily of black and gray shales. Delineation of the different stratigraphic units is based on the occurrence of concretion horizons, bentonite beds, sandstone tongues, lithologic changes, and faunal content. The present paper is concerned largely with that part of the section termed "Carlile

shale" by Thom (1922), Reeside (1923), and Thom et al. (1935). The Carlile shale of Thom (1922) has been included in the Frontier formation by the present author. The reasons for this change will be dealt with later in this paper.

Frontier Formation

The Frontier formation is arbitrarily divided in this paper into seven lithologic units, the facies and faunal relationships of which are illustrated in figure 3.

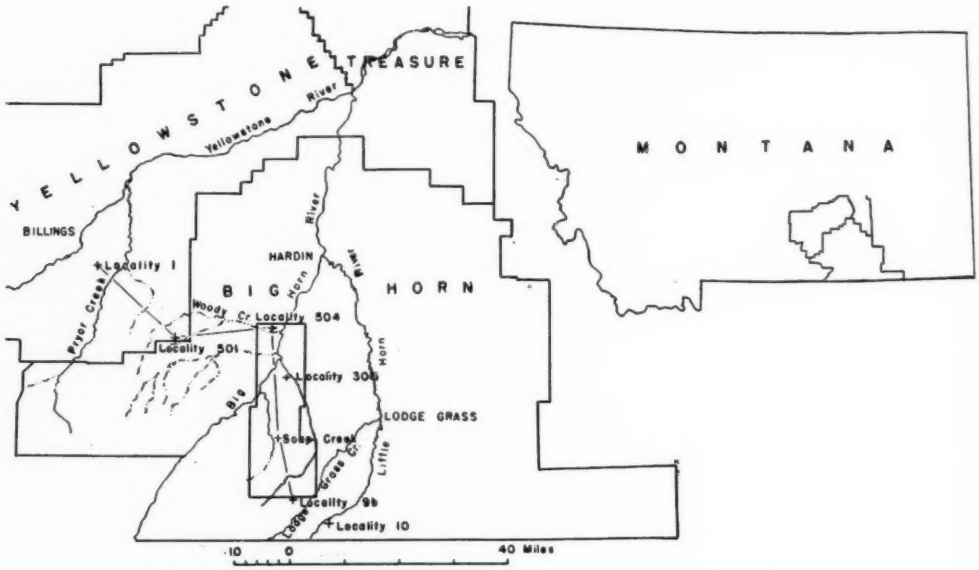

FIG. 1—Index map of Big Horn and Yellowstone Counties, Montana.

Unit One.—Unit one of the Frontier formation consists of black and gray shales with one or more sandy zones. It is equivalent to the Frontier formation of Thom (1922). It overlies the Mowry shale and underlies Unit two of the Frontier formation. This unit can be broken down into a number of smaller units of variable areal extent.

Unit Two.—Unit two of the Frontier formation consists of gray and black shales. Its base is marked commonly by a thick bed of bentonite, and its top is drawn at the base of the cream-colored shales of Unit three. Unit two is more frequently covered and less easily observed than the overlying units. It is estimated to be about 70 feet thick in the northwest part of the area, although not well exposed in that locality. It is about 285 feet thick in the southeastern part of the area. However, it must be remembered that the units are purely lithologic entities and appear to be variable in thickness from exposure to exposure. Further detailed studies may reveal a definite pattern in the lithologic facies of the Frontier formation of this area.

Unit two consists largely of gray and black shales which weather by breaking into fine angular fragments. It contains many small seams of bentonite and one or more thicker beds of bentonite. At the Soap Creek oil field this unit is about 145 feet thick (Thom et al., 1935) and is the lower part of the Carlile shale of Thom (1922). A thick bentonite bed which is evidently the bentonite bed that Thom et al. (1935) used to define the top of the Frontier formation at Soap Creek occurs at the top of the first ridge east of the scarp formed by the Mowry shale. This bentonite bed is here placed at the base of Unit two. It can be traced from the Soap Creek oil field south to Rotten Grass Creek, then to Lodge Grass Creek, and to the south side of the Little

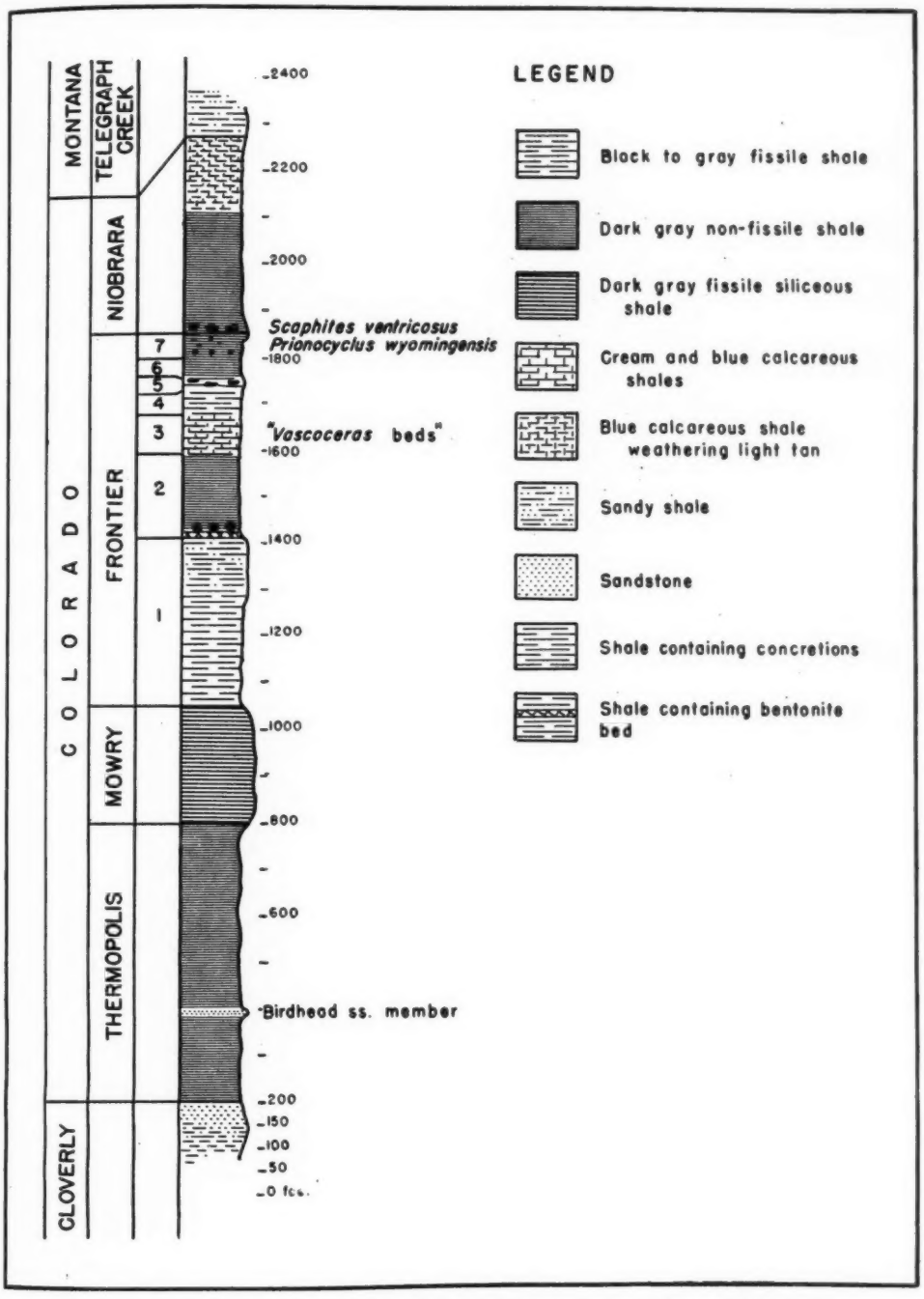

FIG. 2—Generalized stratigraphic section, Colorado group, south-central Montana.

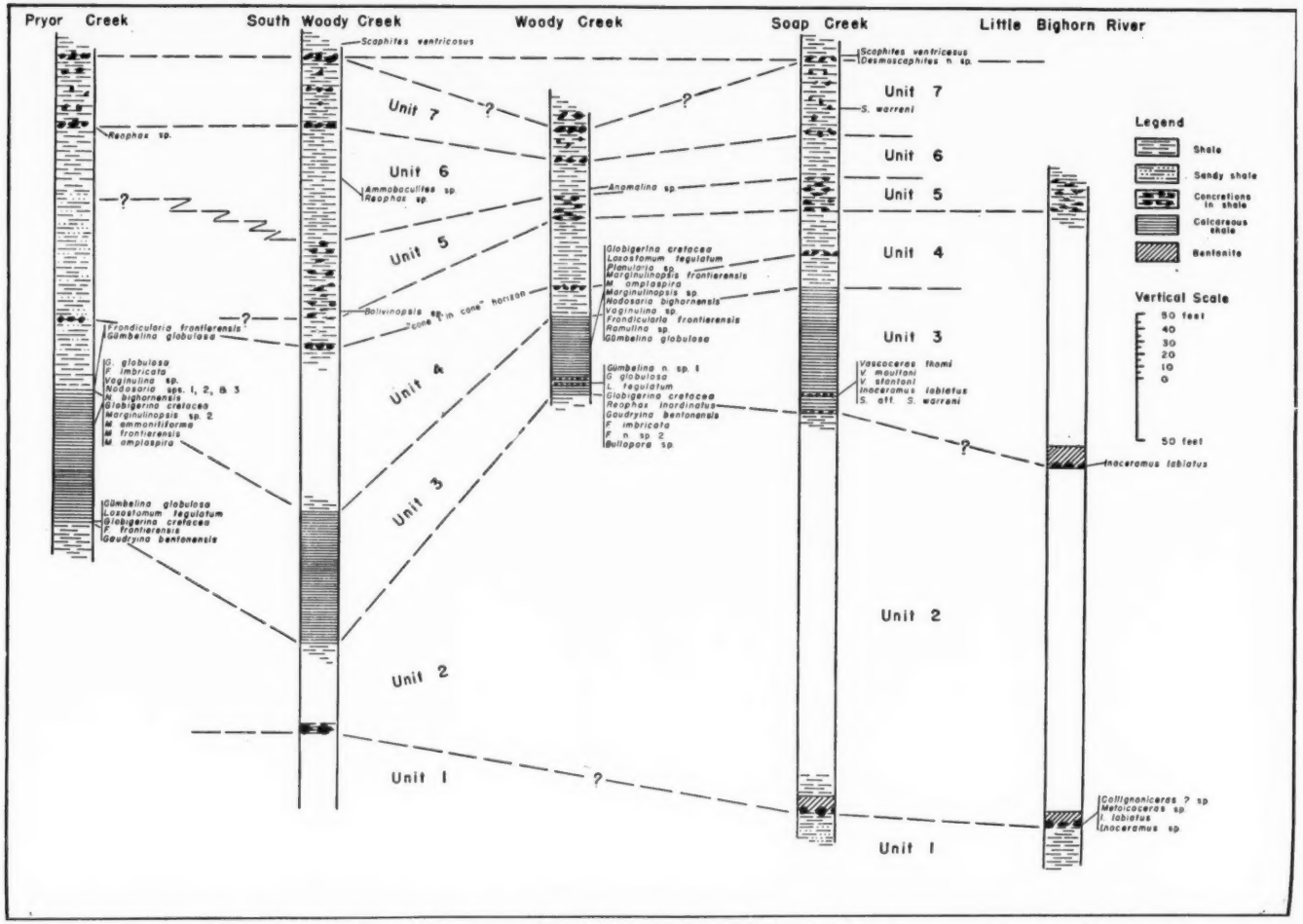

FIG. 3—Diagram of sections of the upper Frontier formation, Big Horn and Yellowstone Counties, Montana.

Horn River. At the latter locality the bentonite was estimated to be from 12 to 15 feet thick. A zone of blue to gray limestone concretions occurs in or at the base of this bentonite bed. These concretions may reach a diameter of from 12 to 15 feet. They weather brown on the surface and are persistent throughout the zone of the bentonite. Neither the bentonite nor the concretions were found on the east side of Woody Creek, secs. 3 and 4, T. 3 S., R. 31 E. They probably underlie the flood plain of Woody Creek. This concretion horizon occurs at approximately the same stratigraphic level on South Woody Creek, sec. 34, T. 3 S., R. 29 E., and on the divide between the Yellowstone River and Pryor Creek, sec. 28, T. 1 S., R. 27 E., but in these two localities the bentonite bed is absent.

The concretionary bentonite horizon at the base of Unit two is of particular interest because it yields the lowest marine fauna reported above the Mowry formation in this area. The fauna is poorly preserved, and many of the forms are not in identifiable condition. *Inoceramus labiatus* Schlotheim, *Inoceramus* sp., *Metoicoceras* sp., and several unidentified pelecypods and cephalopods were obtained from the concretions on Lodge Grass Creek, sec. 26, T. 8 S., R. 33 E. These forms may also be collected from the same concretion horizon on the south side of the Little Horn River, sec. 13, T. 9 S., R. 34 E., locality 10. At this locality the bentonite bed associated with the concretion horizon yielded a large number of fragmental internal molds of large Prionocyclidae (Haas, 1949). Specimens three and four inches in diameter represent only fragments of the outer whorls. No entire specimens occur at this horizon because the fragments are floated out on the bentonite when it swells after the rainy seasons. In the process the cephalopods are broken up into a large number of scattered fragments.

The following Foraminifera were obtained from 20 feet below the top of Unit two on the head of the south fork of Willow Creek, sec. 28, T. 8 S., R. 33 E., Big Horn County, Montana, locality 9b:

Nodosaria bighornensis Young, n. sp.
Gümbelina globulosa (Ehrenberg)
Globigerina cretacea d'Orbigny

A larger and better preserved foraminiferal fauna was obtained from strata 30 feet below the top of Unit two at the same locality. This fauna includes the following forms:

Clavulinoides n. sp.
Dorothia soapcreekensis Young, n. sp.
Lenticulina n. sp.
Planularia n. sp.
Marginulinopsis amplaspira Young, n. sp.
Marginulinopsis frontierensis Young, n. sp.
Frondicularia n. sp. 1
Gümbelina globulosa (Ehrenberg)
Bulimina bulletella Young, n. sp.
Gyroidina n. sp.
Stensioina n. sp.
Globigerina cretacea d'Orbigny
Anomalina bighornensis Young, n. sp.
Cibicides kennedyi Young, n. sp.
Cibicides n. sp.
Vaginulina sp.

Unit Three.—Unit three of the Frontier formation consists of the white calcareous shales in which the *Vascoceras* fauna occurs (Reeside, 1923 and Thom et al., 1935). These strata have been called the "*Vascoceras* beds." Unit three varies considerably in thickness. It is about 100 feet thick at Soap Creek, 50 feet thick at Woody Creek, 105 feet thick at South Woody Creek, and 90 feet thick at Pryor Creek. Beyond a doubt at least part of the variation in thickness is the result of lateral gradation into other lithologic facies. The "*Vascoceras* beds" are typically developed at Soap Creek and are about 100 feet thick.

According to Thom et al., (1935):

> The beds 145 to 245 feet above the base of the Carlile, as here defined, usually contain two layers of bluish limy shale, which at many places along hillsides weather into conspicuous whitish streaks. These limy beds, where exposed in the hills east of Soap Creek oil field, contain numerous concretions, many of which enclose the fossil remains of very large ammonites of the genus *Vascoceras*.

Unit three consists largely of white calcareous shales that weather to a creamy white. In many exposures they alternate with bluish-gray calcareous shales which may also weather white. The bluish-black shales are more abundant toward the top and bottom of the unit, and the unit gradually grades into the overlying and underlying units. Also, there are large white limestone concretions in zones near the base of the unit. These may be fossiliferous, and they may or may not contain geodes of calcite crystals.

FIG. 3—Diagram of sections of the upper Frontier formation, Big Horn and Yellowstone Counties, Montana.

This unit was traced southeast from Soap Creek across Lodge Grass Creek along the strike for about thirteen miles. The unit is not typically developed on the Little Horn River, but may be represented there, at least in part, by the uppermost of the two bentonite beds in sec. 13, T. 9 S., R. 34 E. This bentonite bed occurs at approximately the stratigraphic horizon of the "*Vascoceras* beds," and contains typical concretions with *Inoceramus labiatus* Schlotheim.

The light creamy shales of Unit three can be traced to the north and west of the Soap Creek oil field along the hills northeast of Soap Creek to the mouth of Soap Creek and then north along the east side of the Big Horn River to a point three or four miles northeast of St. Xavier. Unit three here passes under the wide floodplain of the Big Horn River. Because of the vegetation and the attitude of the beds, Unit three could not be traced continuously west of the Big Horn River. However, this unit occurs in typical development, except for the absence of megafossils, on the east side of Woody Creek, secs. 3 and 4, T. 3 S., R. 31 E., and on the divide between the Yellowstone River and Pryor Creek, sec. 28, T. 1 S., R. 27 E., Yellowstone County, Montana. The intergradations of the underlying and overlying lithologic units with the bottom and top of the "*Vascoceras* beds," and the variations in thickness of all the units, indicate that Unit three is not completely contemporaneous throughout its area of deposition.

Reeside (1923) described the following fauna here referred to Unit three.

Vascoceras thomi Reeside
Vascoceras moultoni Reeside
Vascoceras stantoni Reeside
Vascoceras sp.
Pseudotissotia (*Choffaticeras*) sp. ?
Allocrioceras pariense (White) ?
Inoceramus labiatus Schlotheim
Inoceramus sp. undetermined
Ostrea or *Exogyra* sp.

In addition to these as a part of the present work, the following megafossils were found; *Anisomyon* sp. and *Scaphites* aff. *S. warreni* Meek and Hayden. In the stratigraphic and areal studies of the genus *Vascoceras* in this area, fragments of the genus *Vascoceras* were found for about four miles (Fig. 1) along the strike to the southeast of Soap Creek, but no fragments were recovered beyond this point. Specimens of *Vascoceras* were found along the outcrop northwestward to the point of hills east of the entrance of Soap Creek onto the floodplain of the

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EXPLANATION OF PLATE 11

FIGS. *1, 2—Reophax inordinatus* Young, n. sp. *1*, Retouched photograph of holotype, ×58; *2*, retouched photograph of paratype, ×58; both from locality 504, horizon 504-a. (p. 48)

3–6—Dorothia soapcreekensis Young, n. sp. *3, 6*, Retouched photographs of apertural and lateral views of holotype, ×48; *4, 5*, retouched photographs of paratypes, ×48; all from locality 9b, horizon 9b-2. (p. 49)

7, 8—Clavulinoides n. sp. Retouched photographs of apertural and lateral views of a specimen from locality 9b, horizon 9b-2, ×35. (p. 49)

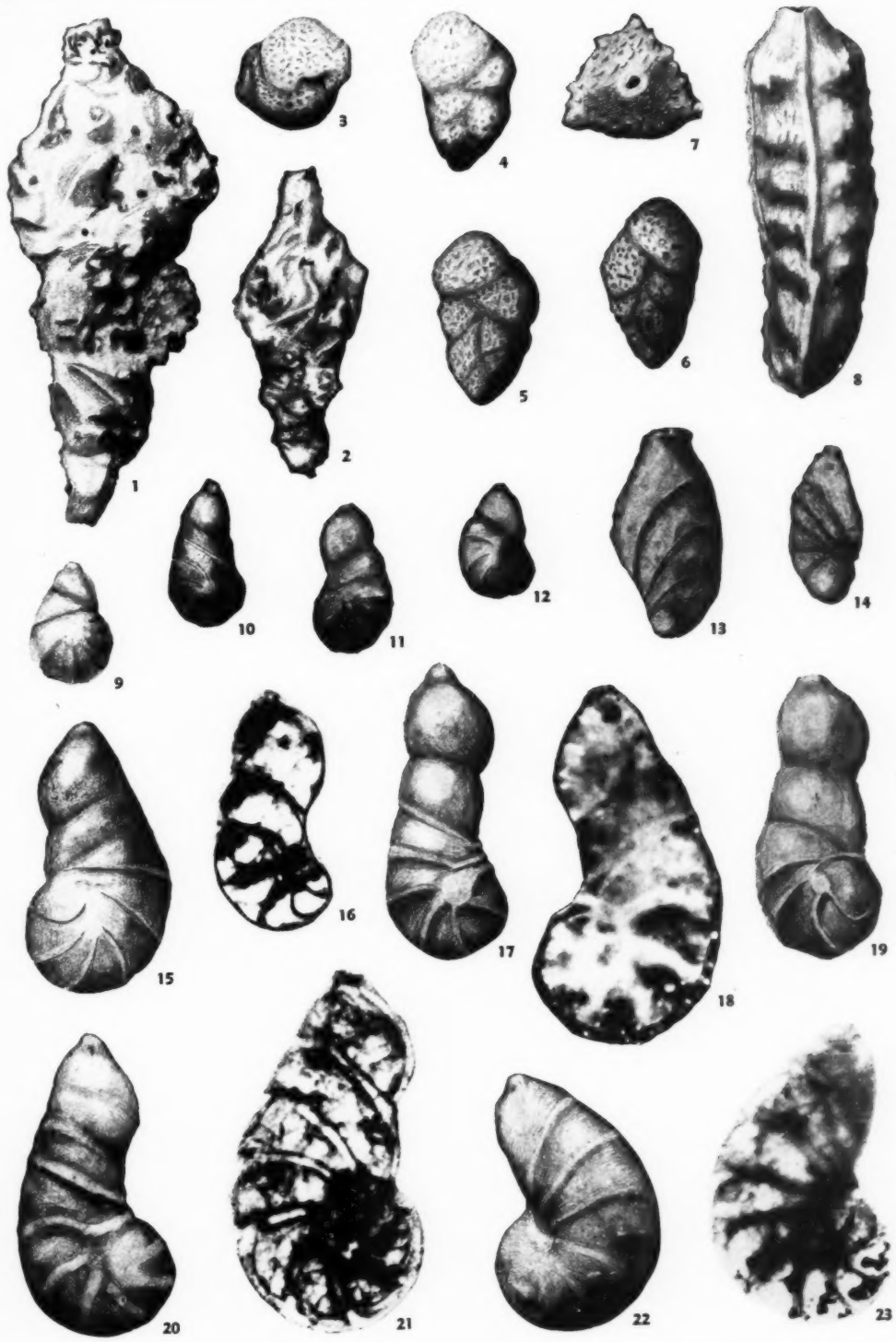
9–12—Marginulinopsis frontierensis Young, n. sp. *9*, Retouched photograph of holotype, ×40 (*See also* text figure 5—3); *10–12*, retouched photographs of three paratypes, ×40; *9*, from locality 9b, horizon 9b-2; *10–12* from locality 504, horizon 504-b. (p. 52)

13, 14—Planularia n. sp. Retouched photographs of two specimens, ×40; *13* from locality 504, horizon 504-b; *14* from locality 9b, horizon 9b-2. (p. 50)

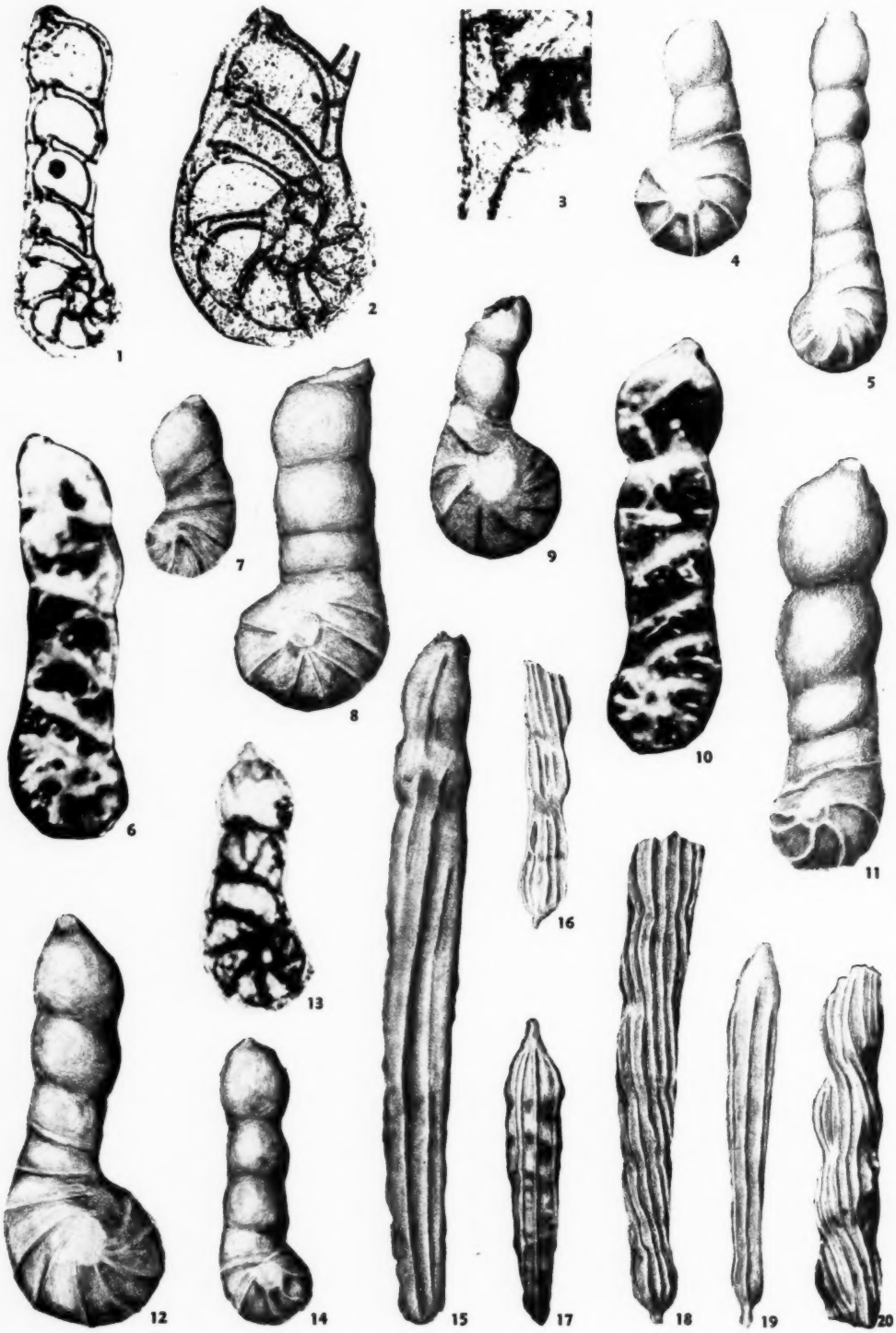
15, 17–21—Marginulinopsis amplaspira Young, n. sp. *15*, Retouched photograph of paratype, ×50 (*See also* text figure 5—18 and this plate, fig. 21); *18*, unretouched photograph of paratype in xylene with reflected light, ×65 (*See also* text fig. 5—21); *21*, unretouched photograph of paratype in xylene with transmitted light, ×65 (*See also* this plate, fig. 15 and text fig. 5—18); *17*, retouched photograph of paratype, ×50 (*See also* pl. 12, fig. 13); *19, 20*, retouched photographs of paratypes, ×50; *18–20* from locality 1, horizon 1-b; *15, 17, 21* from locality 305, horizon 305-a. (p. 54)

16—Marginulinopsis n. sp. 3. Unretouched photograph of specimen in xylene with transmitted light, ×55; locality 305, horizon 305-a (*See also* pl. 12, fig. 7 and text fig. 6—1). (p. 58)

22, 23—Marginulinopsis ammonitiformis Young, n. sp. *22*, Retouched photograph of holotype, ×55; *23*, unretouched photograph of holotype in xylene with transmitted light, ×60; locality 305, horizon 305-a (*See also* text fig. 5—11). (p. 52)



Young, Montana Frontier formation Foraminifera



Young, Montana Frontier formation Foraminifera

Big Horn River. This genus is known to occur along the strike for a distance of about ten miles but could not be found beyond these limits. Stratigraphically, the *Vascoceras* fauna in this area occurs at only the one horizon at the base of the unit here described as Unit three.

Well preserved megafossils are found in the "*Vascoceras* beds" only in concretions. These concretions are highly calcareous, but they contain enough clay to weather rapidly. At the Soap Creek oil field the dips are relatively high on the east side of the field, and freshly eroded scarp slopes expose solid, fresh, unweathered concretions with well preserved fossils. Along the strike away from the Soap Creek dome in either direction, the dips decrease, the scarp slopes are not as steep or as freshly exposed, the concretions are more weathered, and the fossils are not as well preserved. The suggestion is offered here that the limited areal extent of the *Vascoceras* fauna may be the result of the relative rapidity with which the concretions weather after being subjected to hydration but before being exposed at the surface. This conclusion is supported by the lack of complete concretions in areas of less rapid erosion. Thus, the distribution of the *Vascoceras* fauna may not be altogether controlled by an ecological factor, but its limited vertical extent seems to require some ecological explanation.

That a great amount of subsurface weathering takes place is also indicated by the obvious solution pits and cavities in many of the microfossils obtained from below the soil zone.

A large foraminiferal fauna was collected from Unit three in beds equivalent to the "*Vascoceras* beds," and most of the species are new. However, it is interesting to note that this foraminiferal fauna was not obtained in the areas where specimens of *Vascoceras* are known to occur.

The following fauna was procured from the base of the "*Vascoceras* beds" in the westward facing scarp in sec. 28, T. 1 S., R. 27 E., on the divide between the Yellowstone River and Pryor Creek, Yellowstone County, Montana, locality 1.

Frondicularia frontierensis Young, n. sp.
Ramulina sp.
Gümbelina globulosa (Ehrenberg)
Loxostomum tegulatum (Reuss)
Globigerina cretacea d'Orbigny
Gaudryina bentonensis ? (Carman)

At the same locality at which the above fauna was found, the following fauna was obtained from a horizon 20 feet below the

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EXPLANATION OF PLATE 12

FIGS. *1–4, 6, 8–14—Marginulinopsis amplaspira* Young, n. sp. *1–3*, Unretouched photographs of paratype in thin section (*See also* text fig. 6—11, 20), *1* the entire specimen in thin section, ×43, *2* to illustrate the manner of coiling and the proloculus, ×115, and *3* to show the manner of addition of the second linear chamber at the peripheral edge, ×350; *4, 8, 9, 14*, retouched photographs of four paratypes, ×50; *6*, unretouched photograph of paratype in xylene with reflected light, ×50 (*See also* text fig. 6—15); *10–11*, holotype (*See also* text fig. 6—14), *10* unretouched photograph in xylene with reflected light, ×50, and *11* retouched photograph, ×50; *12*, retouched photograph of paratype, ×50 (*See also* text fig. 6—6); *13*, unretouched photograph of paratype in xylene with transmitted light, ×50 (*See also* pl. 11, fig. 17); *6, 8, 10–13* from locality 305, horizon 305-a; *9* from locality 9b, horizon 9b-2; *1–4, 14* from locality 1, horizon 1-b. (p. 54)

5—Marginulinopsis n. sp. 1. Retouched photograph of specimen from locality 305, horizon 305-a, ×60 (*See also* text fig. 6—19). (p. 57)

7—Marginulinopsis n. sp. 3. Retouched photograph of specimen from locality 305, horizon 305-a, ×40 (*See also* pl. 11, fig. 16 and text fig. 6—1). (p. 58)

15—Nodosaria xavierensis Young, n. sp. *15*, Retouched photograph of paratype, ×55; locality 305, horizon 305-a. (p. 59)

16, 18—Nodosaria ? sp. 3. Retouched photographs of specimens from locality 1, horizon 1-b, ×55. (p. 60)

17, 19—Nodosaria bighornensis Young, n. sp. *19*, Holotype ×55; *17*, paratype, ×70; both photographs retouched; *19* from locality 305, horizon 305-a; *17* from locality 504, horizon 504-b. (p. 58)

20—Nodosaria sp. 1. Retouched photograph of specimen from locality 305, horizon 305-a, ×25. (p. 59)

top and 85 feet above the base of the "*Vascoceras* beds."

Marginulinopsis frontierensis Young, n. sp.
Marginulinopsis ammonitiformis Young, n. sp.
Marginulinopsis amplaspira Young, n. sp.
Marginulinopsis n. sp. 2
Nodosaria bighornensis Young, n. sp.
Nodosaria sp. 1
Nodosaria sp. 2
Nodosaria ? sp. 3
Vaginulina n. sp.
Frondicularia imbricata Young, n. sp.
Gümbelina globulosa (Ehrenberg)
Globigerina cretacea d'Orbigny

Frondicularia frontierensis Young, n. sp., and *Gümbelina globulosa* (Ehrenberg) were found at the top of the "*Vascoceras* beds" at the same locality.

The following fauna was obtained from the base of the "*Vascoceras* beds" on the north side of Woody Creek, sec. 3, T. 3 S., R. 31 E., Big Horn County, Montana, locality 504.

Reophax inordinatus Young, n. sp.
Gaudryina bentonensis (Carman)
Frondicularia n. sp. 2
Frondicularia imbricata Young, n. sp.
Gümbelina globulosa (Ehrenberg)
Loxostomum tegulatum (Reuss)
Globigerina cretacea d'Orbigny
Bullopora sp.

The following fauna was obtained from 30 feet above the base of the "*Vascoceras* beds" on Woody Creek, locality 504.

Planularia n. sp.
Marginulinopsis frontierensis Young, n. sp.
Marginulinopsis amplaspira Young, n. sp.
Marginulinopsis sp.
Nodosaria bighornensis Young, n. sp.
Vaginulina n. sp.
Frondicularia frontierensis Young, n. sp.
Ramulina sp.
Gümbelina globulosa (Ehrenberg)
Loxostomum tegulatum (Reuss)
Globigerina cretacea d'Orbigny

The following fauna was found at the mouth of Rotten Grass Creek in an outcrop of the "*Vascoceras* beds" on the hillside just south of Rotten Grass Creek and east of the Big Horn ditch, sec. 1, T. 5 S., R. 32 E., Big Horn County, Montana, locality 305.

Marginulinopsis frontierensis Young, n. sp.
Marginulinopsis ammonitiformis Young, n. sp.
Marginulinopsis amplaspira Young, n. sp.
Marginulinopsis n. sp. 1
Marginulinopsis n. sp. 2
Marginulinopsis n. sp. 3
Marginulinopsis sp.
Nodosaria bighornensis Young, n. sp.
Nodosaria xavierensis Young, n. sp.
Nodosaria sp. 1
Nodosaria sp. 2
Vaginulina n. sp.
Frondicularia frontierensis Young, n. sp.
Gümbelina globulosa (Ehrenberg)
Globigerina cretacea d'Orbigny

Unit Four.—A shale unit which is about 60 feet thick and which occurs below the red concretion zone at Soap Creek is mentioned by Thom et al. (1935). This unit is here referred to Unit four of the Frontier formation. It consists of bluish-black fissile shales which contain small nodular concretions at some places and which are sandy at a few localities. A persistent bed of large blue limestone concretions with cone-in-cone structure is present throughout the area. It may not occur at the same stratigraphic level at all localities. On Pryor Creek these concretions weather out in large discs and are more sandy than at any of the other observed occurrences. The upper part of Unit four is more sandy at Pryor Creek than at other exposures visited.

Unit four increases in thickness to the northwest, reaching a thickness of about 85 feet on the east bank of Woody Creek, sec. 4, T. 3 S., R. 31 E., and a thickness of more than 150 feet at South Woody Creek, sec. 34, T. 3 S., R. 29 E. However, at South Woody Creek the section was heavily overgrown with vegetation, and the boundaries of the unit were estimated. On the divide between the Yellowstone River and Pryor Creek, sec. 28, T. 1 S., R. 27 E., this unit thins to approximately 80 feet. This part of the section was completely overgrown with vegetation and the thickness could not be determined on the Little Horn River.

No fossils were found in Unit four, and none has been reported by other workers.

Unit Five.—Unit five consists of black shales containing flat red concretions. It has been called the "red-dinner-plate" zone or "red chip" zone by many geologists. These concretions are typically from six inches to two feet in length, longer than wide, and from one to three or four inches thick. They are composed of a gray calcareous and argillaceous material heavily cemented with siderite, the latter oxidizing at the surface

of the concretions to produce the typical red color. On the outcrop these concretions may be scattered over the surface or they may break down into a red "chip" float that is very typical of the unit in more weathered exposures. Unit five is about 30 feet thick at Soap Creek (Thom et al., 1935) and increases to a thickness of slightly more than 60 feet in the section at South Woody Creek, sec. 34, T. 3 S., R. 29 E. This unit or its equivalents may thicken to the west.

This unit is not typically developed farther west and north in the exposures on the divide between Pryor Creek and the Yellowstone River, sec. 28, T. 1 S., R. 27 E. It is here replaced by a series of alternating sandstones and sandy shales. The sandstones are thin, about one-half inch in thickness, highly calcareous, and alternate with thin beds of black fissile shale which are sandy at some horizons. Unit five cannot be differentiated from Unit four or Unit six at Pryor Creek. At this locality the sandy facies ranges from beds equivalent to Unit four up into strata equivalent to the lower part of Unit six. This sandy facies may represent the eastward extensions of some of the Frontier sandstones known to occur farther west (Downs, 1947 and Hewitt, 1914).

The base of Unit five is easily identified on the south side of the Little Horn River, even though the underlying unit is covered.

The following megafauna is reported from Unit five (Thom et al., 1935).

Baculites gracilis Shumard
Inoceramus fragilis Hall and Meek
Inoceramus cf. *I. lamarcki* Parkinson
Prionocyclus wyomingensis Meek
Veniella humilis Meek and Hayden
Collignoniceras Breistroffer (=*Prionotropis* Meek non Fieber)
Lunatia ? sp.
Scaphites warreni Meek and Hayden
Volutoderma ? sp.

In addition to the above forms, Reeside (1923) reports *Collignoniceras* aff. *C. woolgari* (Mantell). One specimen of *Bolivinopsis* sp. was obtained in the present work from near the base of Unit five on South Woody Creek, sec. 34, T. 3 S., R. 29 E., Yellowstone County, Montana.

Unit Six.—Unit six of the Frontier formation as used in this paper consists of about 35 feet of dark gray to black shale overlying the flat red concretion zone (Thom et al., 1935). It underlies Unit seven. Unit six varies in thickness throughout the Crow Indian Reservation, being about 25 feet thick on Woody Creek, sec. 4, T. 3 S R. 31 E., and about 90 feet thick on South Woody Creek, sec. 34, T. 3. S., R. 29 E. It could not be determined if the unit actually thickened to this extent or if the concretion horizons defining its top and bottom migrate up and down in the section.

Prior to this paper no fossils had been reported from this area in beds referable to Unit six. *Ammobaculites* sp. and *Reophax* sp. were found in the middle of Unit six on South Woody Creek, sec. 34, T. 3 S., R. 29 E., and *Anomalina* sp. was found near the base of the unit on Woody Creek, sec. 4, T. 3 S., R. 31 E., Big Horn County, Montana. Throughout most of this area Unit six is underlain by the flat red concretion zone (Unit five of the Frontier formation in this paper). However, in the section measured in sec. 28, T. 1 S., R. 27 E., the underlying concretion zone is absent, and Unit six grades downward into a sandy phase that may or may not be equivalent to the flat red concretion zone of Unit five.

Unit Seven—The top unit of the Frontier formation consists of black shale at the Soap Creek oil field, Big Horn County, Montana, and in sec. 28, T. 1 S., R. 27 E., on the divide between Pryor Creek and the Yellowstone River, Yellowstone County, Montana. This shale weathers by breaking down into fine angular fragments and develops a bluish-gray soil. At different localities this unit may contain blue calcareous concretions scattered through it. These concretions weather white and may reach a diameter of from eighteen inches to two feet. A zone of large blue calcareous concretions, weathering to a yellow color and having a diameter of from four to five feet, occurs at the base of the unit.

The white concretions typically scattered through this unit are not present or are rare at many localities. However, the basal zone of large yellow concretions is conspicuous throughout the area, except in sections in the vicinity of the Little Horn River near the Montana-Wyoming border. In the southern part of Big Horn County, Montana, in that area from the Little Horn

River south to the Montana-Wyoming boundary, the entire section takes on a different aspect and many units cannot be correlated. Unit seven attains a thickness of about 50 feet on South Woody Creek and a thickness of about 58 feet on the divide between the Yellowstone River and Pryor Creek. The typical concretion zones are not fully developed in Unit seven on Woody Creek, sec. 4, T. 3 S., R. 31 E., Big Horn County, Montana. It may be that part of the uppermost Frontier is either absent or not fully developed at this locality.

Reeside (1923) reports the following fossils from this unit of the Frontier.

Corbula aff. C. *nematophora* Meek
Fusus ? sp.
Inoceramus labiatus Schlotheim
Prionocyclus wyomingensis Meek
Pseudomelania ? sp.
Veniella goniophora Meek

In addition to these fossils, *Scaphites warreni* Meek and Hayden was found in this work in Unit seven on the corner of the high mesa about two and one-half miles southeast of the Wolf Ranch house on Soap Creek, Big Horn County, Montana. The reported occurrence of *Inoceramus labiatus* Schlotheim in this horizon is anomalous. This form is generally restricted to the Greenhorn limestone and the lower Carlile shale and their equivalents farther south in Wyoming and Colorado. In the present work *Inoceramus labiatus* Schlotheim was not found at this horizon. Instead, *Inoceramus fragilis* Hall and Meek which characterizes the upper Frontier and its equivalent, the Carlile shale, was obtained here. Except for *Inoceramus labiatus* Schlotheim, the fauna reported by Reeside is characteristic of the upper Frontier formation and the Carlile shale.

The only foraminifer obtained from this unit of the Frontier formation was a fragmental specimen of *Reophax* sp. from about 55 feet below the top of the Frontier in the westward facing scarp in sec. 28, T. 1 S., R. 27 E., on the divide between the Yellowstone River and Pryor Creek, Yellowstone County, Montana.

Niobrara Formation

Thom (1922) placed the base of the Niobrara formation at a zone of large blue calcareous concretions which weather brownish-yellow. This particular zone at Soap Creek (Thom et al., 1935) overlies about 50 feet of dark shale containing numerous white concretions.

At all localities visited on the Crow Indian Reservation the basal strata of the Niobrara formation consist of gray to black shales. These shales may be finely fissile, but generally fall apart into fine angular fragments upon weathering. When sufficiently highly weathered, they may develop a bluish tinge. As mentioned above, the base of the Niobrara formation is placed at a horizon of large blue calcareous concretions. These concretions have an average diameter of from three to four feet and weather to a brownish-yellow.

Reeside (1923) lists the following fauna from this horizon:

Yoldia sp.
Nemodon sp.
Barbatia n. sp.
Inoceramus fragilis (Hall and Meek) ?
Inoceramus (*Actinoceramus*) n. sp.
Veniella goniophora Meek
Callista tenuis (Hall and Meek)
Corbula cf. *C. nematophora* Meek
Dentalium sp.
Gyrodes aff. *G. petrosa* (Morton)
Turritella aff. *T. whitei* Stanton
Anchura sp.
Nautilus sp.
Baculites sp.
Scaphites vermiformis Meek and Hayden

In addition to these, Thom et al. (1935) list *Gyrodes* cf. *G. conradi* Meek, *Inoceramus umbonatus* ? Meek and Hayden, and *Ostrea congesta* Conrad. This assemblage shows some Niobrara and some Carlile affinities and probably represents a mixed fauna. *Inoceramus fragilis* Hall and Meek and *Turritella whitei* Stanton are typical of the upper Frontier and its equivalent, the Carlile shale, of other areas. These two forms have close relatives in the above fauna. *Scaphites vermiformis* Meek and Hayden and *Inoceramus umbonatus* Meek and Hayden are reported as typical of the Niobrara formation in other areas.

STRATIGRAPHIC AND FAUNAL CONCLUSIONS

It is recommended that the term Carlile shale of Thom (1922), Reeside (1923), and Thom et al. (1935) be repressed in such a way that the term Frontier formation will

include those strata originally designated as Frontier plus the beds designated Carlile shale (Thom, 1922). The strata in the original Carlile shale section of this area are equivalent to the upper Frontier formation of eastern and southeastern Wyoming. The suppression of the term Carlile in favor of the term Frontier is based mainly on paleontological evidence. The following discussion assembles the data on the various formations involved in the Carlile-Frontier problem.

Type Localities.—The name Niobrara was given by Meek and Hayden (1861, pp. 417–442) to rocks exposed in the bluffs along the Missouri River near the mouth of the Niobrara River, Knox County, Nebraska.

Gilbert (1896, pp. 565–567) divided the Benton of the Arkansas Valley of Colorado into the Graneros shale at the base, the Greenhorn limestone in the middle, and the Carlile shale at the top. The Carlile shale consists largely of shale in the type locality; the upper part of the formation is sandy to the west. It is about 200 feet thick.

The Frontier formation (Knight, 1902) consists of about 2000 feet of coal-bearing sandstones and shales in the type area of southwestern Wyoming. Unfortunately, by usage, the Frontier formation as a rock unit has outgrown the type area and as used in eastern Wyoming does not cover the same span of geologic time as it does in the type area (Thomas, 1936). The Frontier formation as used in northwestern Wyoming and southwestern Montana is also different from that originally defined in the type area. In northwestern Wyoming and southwestern Montana the Frontier formation has at the top the Torchlight sandstone member (Hintze, 1915), now generally called the "1st Wall Creek sandstone." In eastern Wyoming the Frontier formation has at its top the Wall Creek sandstone (1st Wall Creek sand of the Salt Creek area).

Frontier Faunas.—Thomas (1936) reported *Prionocyclus wyomingensis* Meek and *Inoceramus fragilis* Hall and Meek from the Wall Creek sandstone, and *Scaphites warreni* Meek and Hayden from the upper Frontier formation.

Carlile Faunas.—Dane, Pierce, and Reeside (1937) reported the following fauna from the Codell sandstone member of the Carlile shale in eastern Colorado:

Inoceramus fragilis Hall and Meek
Inoceramus dimidius White
Inoceramus sp.
Ostrea lugubris Conrad
Ostrea sp.
Gryphaea sp.
Scaphites warreni Meek and Hayden
Prionocyclus wyomingensis Meek
Lamna ? sp.
Ptychodus sp.

They recorded *Inoceramus* sp., *Ostrea* sp., *Baculites* sp., *Allocrioceras* cf. *A. pariense* (White) and *Collignoniceras* (=*Prionotropis* Meek, non Fieber) *woollgari* (Mantell) from the Fairport chalky shale member of the Carlile shale. In addition to the faunas reported by Dane, Pierce, and Reeside, Bass (1926) reported *Ostrea congesta* Conrad (float) and *Corax* sp. from the Codell sandstone member; and *Prionocyclus wyomingensis* Meek from the Blue Hill shale member. Bass also reported the following fauna from the Fairport chalky member of the Carlile shale:

Inoceramus fragilis Hall and Meek
Inoceramus labiatus Schlotheim (broad variety)
Ostrea cf. *O. congesta* Conrad
Baculites gracilis Shumard
Ichthyodectes ? sp.
Globigerina bulloides d'Orbigny

Niobrara Faunas.—*Inoceramus deformis* Meek occurs in the Sage Breaks shale member of the Niobrara formation in the Laramie Basin, Wyoming (Thomas, 1936).

The Niobrara formation of eastern Colorado contains the following fauna (Dane, Pierce, and Reeside, 1937):

Inoceramus deformis Meek ?
Ostrea congesta Conrad
Baculites codyensis Reeside
Scaphites ventricosus Meek and Hayden
Baculites asper Morton
Scaphites vermiformis Meek and Hayden
Placenticeras sp.
Texanites cf. *T. pseudotexanus* Grossouvre

The absence of *Inoceramus fragilis* Hall and Meek, *Inoceramus labiatus* Schlotheim, *Prionocyclus wyomingensis* Meek, *Scaphites warreni* Hall and Meek, and species of *Collignoniceras* in the Niobrara formation is important. These species are typical of the Carlile shale and upper Frontier formation. Likewise, the absence of *Inoceramus deformis* Meek, *Scaphites vermiformis* Meek and Hayden, *Scaphites ventricosus* Meek and Hayden, and species of *Texanites* in the Carlile and upper Frontier is important as

these forms have not been reported to occur below the Niobrara formation.

Unit seven of the Frontier formation as used in this paper contains *Scaphites warreni* Meek and Hayden, *Inoceramus fragilis* Hall and Meek, and *Prionocylus wyomingensis* Meek, all typical of the Carlile shale of the type region. No megafossils have been reported from Unit six of the Frontier formation of southern Montana. Unit five of the Frontier formation of southern Montana contains *Inoceramus fragilis* Hall and Meek, *Prionocyclus wyomingensis* Meek, *Colligoniceras* sp., and *Scaphites warreni* Meek and Hayden, all characteristic of the Carlile in the type region.

Although some fossils, such as *Inoceramus labiatus* Schlotheim and *Inoceramus fragilis* Hall and Meek, have been reported to transcend the Frontier-Niobrara boundary in southern Montana, such Niobrara fossils as *Scaphites vermiformis* Meek and Hayden and *Scaphites ventricosus* Meek and Hayden have not been reported below the base of the Niobrara. Thomas (1936) correlates the upper Frontier of the Laramie Basin, Wyoming, with the Carlile of the type region on the basis of faunal and stratigraphic evidence.

Although the top of Unit seven of the Frontier formation may not be exactly equivalent to the Niobrara-Carlile boundary in Colorado and to the Niobrara-Frontier boundary in eastern Wyoming, it appears to be as close to this boundary as any lithologic horizon that can be readily determined in the field. The upper part of the Frontier formation, as generally defined in eastern Wyoming and southeastern Wyoming, is equivalent to the Carlile faunally. The "Carlile shale" of previous workers in southern Montana is equivalent to the Carlile faunally and also equivalent to the upper part of the Frontier formation of eastern Wyoming. The term Carlile is not applied

<table>
<tr><th>Southern Montana
Thom et al., 1935</th><th>Southern Montana
This Paper</th><th>Southeastern
Wyoming</th><th>Eastern
Colorado</th></tr>
<tr><td>Niobrara</td><td>Niobrara</td><td>Niobrara</td><td>Niobrara</td></tr>
<tr><td>Carlile</td><td rowspan="2">Frontier</td><td rowspan="2">Frontier</td><td>Carlile</td></tr>
<tr><td>Frontier</td><td rowspan="2">Greenhorn</td></tr>
<tr><td>Mowry</td><td>Mowry</td><td>Mowry</td><td>Graneros</td></tr>
</table>

FIG. 4—Correlation chart showing the rock terms applied to the Frontier formation and adjacent rock units of eastern Colorado, southeastern Wyoming and southern Montana.

in this paper to any rocks of southern Montana, and it is recommended that the term Carlile be discontinued as a rock name in southern Montana. The Frontier formation is extended to include the "Carlile shale" of previous workers in this area (Fig. 4). With this modification, the Frontier formation of southern Montana includes all strata from the top of the Mowry formation to the base of the Niobrara formation and becomes more nearly the stratigraphic equivalent of the Frontier formation of eastern Wyoming and southeastern Wyoming. Further clarification of the stratigraphic nomenclature awaits more definite information regarding the age of the Frontier formation at its type locality.

EVALUATION OF THE MICROFAUNA

Eleven foraminiferal species have been described from the Greenhorn limestone (Morrow, 1934). These eleven species are distributed among eight genera. The eight species described by Carman (1929) are referred to six genera. The two species from the Ashville beds of Manitoba (Wickenden, 1932) represent two genera that have not been reported from rocks of Turonian age in the Rocky Mountain region. The fauna from the Eagle Ford formation described by Moreman (1927) is from the Eagle Ford-Austin chalk transition zone and probably contains some Austin forms. It contains eleven species referable to ten genera. Cushman (1946) described some two dozen species from those American Upper Cretaceous rocks that have been referred to the Turonian stage. Cushman described twenty species, referable to eighteen genera, from the Eagle Ford formation.

The microfauna described in this paper includes thirty-four species referred to seventeen genera. It is difficult to compare the Frontier microfauna with other American microfaunas for the following reasons: Twenty-two genera of Foraminifera are recognized in the Frontier formation of southern Montana. Fourteen of the genera recognized in the Frontier are also known from the Niobrara. Thirty-two genera have been described from the Niobrara (Loetterle, 1937; Morrow, 1934; Carman, 1929). Of twenty-one genera that have been described from the Eagle Ford formation (Cushman, 1946; Moreman, 1927), eight occur in the fauna from the Frontier formation of southern Montana. The Niobrara fauna and most of the Eagle Ford foraminifers, so far described, occur above the *Collignoniceras woollgari* (Mantell) zone. The microfauna from the Frontier of southern Montana occurs below the *Collignoniceras woollgari* (Mantell) zone. Of the seven genera described from the Greenhorn limestone (Morrow, 1934), three occur in the Frontier formation of southern Montana.

The above brief analysis does indicate considerable difference in ecological conditions between the foraminiferal assemblages of the Niobrara formation, Greenhorn limestone, Eagle Ford formation and those of the Frontier formation of southern Montana.

ENVIRONMENTAL CONDITIONS DURING FRONTIER DEPOSITION

The microfauna described in this paper is from the "*Vascoceras* beds" (Unit three), from 20 feet below the "*Vascoceras* beds" (Unit two), and from 30 feet below the "*Vascoceras* beds" (Unit two). About eighty samples were washed from Units two, three, four, five, six, and seven of the Frontier formation. The faunas here described were obtained from seven horizons at four localities. Marine megafossils occur in Units four, five, and seven, but only in concretions. Only a few specimens of crushed foraminiferal tests were obtained from these units. It is possible, therefore, that the sea bottoms were too muddy for benthonic organisms during most of Frontier time. *Ostrea congesta* Conrad is scattered profusely through the shales of the Niobrara formation in sec. 32, T. 2 S., R. 31 E., east of Woody Creek. This seems to indicate that during at least part of Niobrara time deposition was sufficiently slow in some areas to allow the accumulation of individual oysters on the sea floor. However, it seems that such conditions did not prevail during lower Niobrara and Frontier time, presumably either because of muddy bottom conditions or brackish water conditions. The presence of several genera of molluscs in concretions in the upper Frontier of southern Montana indicates that the water conditions during that time were not adverse to marine life. The presence of almost perfect

bedding in the shales of the Frontier formation indicates that bottom scavengers were not numerous.

The "*Vascoceras* beds," Unit three, are highly calcareous shales in which foraminifers of bottom dwelling types are common. This indicates that during the deposition of this unit sedimentation was sufficiently slow to allow the development of a benthonic faunule.

Fossils were recovered from the top and the base of Unit two, but none were found in the intervening strata. No fossils were recovered from Unit one. However, these units show definite indications of having had unfavorable sea floor environments. This is shown by the high content of iron sulphates on their weathered surfaces throughout the area. Unfavorable environmental conditions of Units one and two are further indicated by the presence of microscopic pieces of coalified woody tissue and coalified twigs, and by the presence of encrusted euhedral microscopic crystals of gypsum. The gypsum and the iron sulphates probably result from surface oxidation and hydration of iron sulphides. The absence of remains of planktonic forms, such as *Globigerina*, may be due to their later destruction by acid ground waters. The major portions of Units one and two seem to have been untenable for bottom dwelling organisms. The absence of visible evidence of organic life in Unit six is as yet unexplained. Unit six is also generally free of concretions.

COLLECTING LOCALITIES

Locality 1.—Upper Frontier formation in the westerly facing scarp in sec. 28, T. 1 S., R. 27 E., on the divide between the Yellowstone River and Pryor Creek, Yellowstone County, Montana; *horizon 1-a*, the base of the "*Vascoceras* beds" (base of Unit three); *horizon 1-b*, 20 feet below the top of the "*Vascoceras* beds" (Unit three); *horizon 1-c*, top of the "*Vascoceras* beds" (Unit three).

Locality 504.—Upper Frontier formation on the east side of Woody Creek, sec. 3, T. 3 S., R. 31 E., Big Horn County, Montana; *horizon 504-a*, the base of the "*Vascoceras* beds" (base of Unit three); *horizon 504-b*, 30 feet above the base of the "*Vascoceras* beds" (Unit three).

Locality 305.—Upper Frontier formation on the side of the hill just south of Rotten Grass Creek and east of the Big Horn ditch, sec. 1, T. 5 S., R. 32 E., Big Horn County, Montana; *horizon 305-a*, from the "*Vascoceras* beds" (Unit three).

Locality 9b.—Upper Frontier formation on the head of the south fork of Willow Creek, sec. 28, T. 8 S., R. 33 E., Big Horn County, Montana; *horizon 9b-1*, 20 feet below the "*Vascoceras* beds" in Unit two; *horizon 9b-2*, 30 feet below the "*Vascoceras* beds" in Unit two.

SYSTEMATIC DESCRIPTIONS

Phylum PROTOZOA
Class SARCODINA
Order FORAMINIFERA
Family REOPHACIDAE
Genus REOPHAX Montfort 1808

REOPHAX INORDINATUS Young, n. sp.
Plate 11, figures 1, 2

Test elongate, tapering from the center of the last chamber to the initial end and tapering rapidly toward the aperture from the center of the last chamber; wall coarsely arenaceous, composed largely of quartz grains cemented with calcareous material; surface very irregular and granular; chambers averaging about three in number, slightly broader than long, increasing rapidly in size; sutures may be slightly depressed, frequently invisible; aperture terminal; neck irregular, crooked, obviously protruding; frequently a neck-like spine at the initial end; internal structures concealed by the coarse granularity of the test; length, 0.82 mm. to 1.57 mm.; width, 0.33 mm. to 0.57 mm.; dimensions in mm. of several specimens as follows:

Specimen	*Length*	*Width*
holotype	1.03	0.45
paratypes	1.06	0.39
	1.57	0.57
	0.85	0.33
	1.06	0.39
	0.85	0.33
	0.82	0.33

Remarks.—*Reophax inordinatus*, n. sp., is associated with *Gümbelina globulosa* (Ehrenberg), *Frondicularia imbricata* Young, n. sp., *Globigerina cretacea* d'Orbigny, and a single specimen of *Gaudryina bentonensis*

(Carman). No forms of *Marginulinopsis* Silvestri or any of the Anomalinidae were found in this faunule.

Occurrence.—*Reophax inordinatus*, n. sp., is common at the base of the "*Vascoceras* beds" (Unit three) at locality 504, horizon 504-a. It was not found at any other localities.

Depository.—University of Wisconsin (UW) type collection, Madison, Wisconsin; holotype, number 1; paratypes, number 2.

Family VERNEUILINIDAE
Genus CLAVULINOIDES Cushman 1936
CLAVULINOIDES n. sp.
Plate 11, figures 7, 8

Test finely agglutinated, composed of minute grains of quartz and particles of calcareous material, heavily cemented, smoothly finished, trilateral, with sharp, evenly extended, longitudinal carinae; lateral outline comparatively straight, tapering rapidly at the proximal end of the triserial portion of the test; one edge slightly concave, the other two slightly convex; early chambers triserial and rapidly expanding, giving the initial extremity a pyramidal appearance; before the uniserial attitude is achieved one biserial pair of chambers indicated by a slight anomalous indentation in the two convex carinae at the distal end of the triserial portion of the test; sutures indistinct in the early portion, depressed in the uniserial portion, but not sufficiently depressed to indent the carinate edges; aperture a round opening in the protruding neck at the distal end of the final chamber; length of specimen 1.42 mm.; width of specimen 0.45 mm.; length of triserial stage 0.30 mm.; length from the last suture to the termination of the aperture 0.33 mm.

Remarks.—One complete and one fragmental specimen of *Clavulinoides* n. sp. occur in the collection from the Frontier formation. This species more closely resembles *Clavulinoides trilatera* (Cushman) than other described species. However, the Frontier species has more carinate edges and the chambers do not become inflated distally.

Occurrence.—Two specimens of *Clavulinoides* n. sp. were found 30 feet below the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, number 3.

Family VALVULINIDAE
Genus DOROTHIA Plummer 1931
DOROTHIA SOAPCREEKENSIS Young, n. sp.
Plate 11, figures 3–6

Test stout, subquadrate in transverse section, corners rounded, rounded initial extremity, composed of fine grains of quartz and calcite held together with a large amount of cement, smoothly finished; initial chambers arranged in a trochoid spire and gradually expanding for about three volutions, approaching biseriality in the fourth volution, biserial portion still obtaining a slight twist of about 20 or 30 degrees; chambers in the biserial portion are appressed, varying from slightly inflated in the earlier portion to distinctly inflated in the adult chambers; sutures smooth to slightly depressed in the trochoid spire; becoming distinctly depressed in the biserial stage; aperture a low subquadrate arch at the median base of the final chamber; length 0.51 to 0.60 mm.; width 0.33 to 0.37 mm.; dimensions in mm. of several specimens as follows:

Specimen	*Length*	*Width*
holotype	0.57	0.36
paratypes	0.54	0.34
	0.54	0.37
	0.60	0.37
	0.51	0.33

Remarks.—*Dorothia soapcreekensis*, n. sp., is stouter and more quadrate in outline than *D. bulleta* (Carsey). The Frontier species does seem to be closely related to *D. conula* (Reuss). However, in contradistinction to that species *D. soapcreekensis*, n. sp., possesses more distinct sutures in the early portions of the test and the sutures are not arranged at right angles to the linear axis, sloping away from the axis proximally.

Occurrence.—*D. soapcreekensis*, n. sp., is rare in the Frontier formation of southern Montana and all of the specimens came from one horizon 30 feet below the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, holotype, number 4; paratypes, number 5.

Family LAGENIDAE
Subfamily NODOSARIINAE
Genus LENTICULINA Lamarck 1804
LENTICULINA n. sp.
Figure 5-1

Test subquadrate in peripheral outline, evolute, small, smooth very finely perforate; keel low, round, inconspicuous; chambers closely appressed and probably involute in the earlier stages; last half of the outer volution at about five or six chambers from the aperture becoming evolute, but about three chambers from the aperture breaking sharply at the periphery and returning to the normal manner of coiling; about nine chambers in the outer volution; chambers slightly inflated; sutures depressed, extending from a large umbilical boss toward the periphery with very little curvature; aperture radiate, located in a protuberance at the junction of the septal face with the periphery; dimensions of two specimens: maximum diameter 0.38 and 0.39 mm.; minimum diameter 0.29 and 0.30 mm.; thickness 0.19 and 0.18 mm.

Remarks.—*Lenticulina* n. sp. from the Frontier formation of southern Montana more closely resembles *L. rotulata* Lamarck than other species of this genus, but it is less involute, and the peculiar type of coiling is more pronounced. The sutures of the Frontier species are not limbate.

Occurrence.—Two specimens were collected from 30 feet below the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, number 6.

Genus PLANULARIA Defrance 1824
PLANULARIA n. sp.
Plate 11, figures 13, 14

Test elongate, much compressed throughout, first three or four chambers more or less openly coiled with later chambers oblique along a linear axis; proloculus large and inflated more than any of the chambers, the greatest thickness of the specimen occurring at the proloculus; aperture located in a large terminal protuberance which is much larger than the opening which it contains; orifice primitive radiate, a small slit with two smaller auxiliary slits extending laterally on each side. Dimensions in mm. as follows: length 0.57 and 0.78 mm.; width 0.30 and 0.48 mm.

Remarks.—The two crushed specimens illustrated may not be conspecific. They seem to resemble the forms of *Cristellaria planiuscula* (Reuss) described by Chapman (1917). However, the aperture of the Frontier species differs from the aperture of Chapman's in that Chapman's illustrated specimen seems to have a normal radiate aperture. The aperture of "*Cristellaria*" *planiuscula* Reuss, 1862, is not described in the text material, but is obviously radiate from his illustration. Likewise Chapman does not describe the aperture of his specimen. His illustration is not very clear, leaving some of the features in doubt.

Occurrence.—One specimen of *Planularia* n. sp. was collected in the upper Frontier formation 30 feet above the base of the "*Vascoceras* beds," Unit three, locality 504, horizon 504-b. The other specimen was obtained from 30 feet below the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, number 7.

Genus MARGINULINOPSIS Silvestri 1904

Species of the genus *Marginulinopsis* make up a large part of the upper Frontier microfauna both in number of specimens and of species. The chambers of the coiled series in this genus are closely appressed and usually make up one or more volutions. The later portion is uncoiled and contains from one to many chambers in the different species. Among Frontier species the uncoiled portion is first subcircular in transverse section and becomes circular in the gerontic stage. The later chambers may be highly inflated. The aperture is radiate. It is terminal and central only in *Marginulinopsis* n. sp. 1. The aperture varies somewhere between peripheral and centro-terminal in other species.

Because of the large number of specimens of *Marginulinopsis* in the Frontier fauna an attempt was made to determine the amount of variation that occurs in the different species. Approximately eighty specimens of *Marginulinopsis* were studied and photo-

graphed in xylene.* Tracings of many of these photographs appear on Figures 5 and 6. The object of these studies was threefold; (1) to facilitate the determination of the number of chambers in the coiled series, (2) to determine the manner and variations in coiling, and (3) to determine if there were variations in the size of the proloculus.

Studies in xylene, or other light hydrocarbons, facilitate the determination of the number of chambers and the manner in which they are coiled, unless the tests are filled with dense foreign material.

Studies in the manner of coiling have developed some interesting aspects. First, no definite phylogenetic relationships could be determined between the different species. Some of the forms were too rare for group studies. However, these studies did result in the accentuation of the species by illustrating more clearly the discontinuities between the different species.

Variations in the sizes of the proloculi were not sufficient in any of the species to demonstrate the presence of microspheric and megalospheric forms. The size of the proloculus cannot be used as a specific character in these forms. The diameter of the proloculus cannot be correlated with morphologic types.

The migration of the aperture can be determined easily in many of the specimens. In some gerontic specimens of *Marginulinopsis amplaspira* Young, n. sp., although the aperture never reaches a centro-terminal position, it does migrate slightly toward the periphery after migrating away from the periphery in earlier stages.

One excellent thin-section of *Marginulinopsis amplaspira* Young, n. sp., illustrates the manner of addition of chambers in this species (Pl. 12, figs. 1–3). Presumably chambers were added by allied species in a similar manner. The plane of junction of the walls of adjacent chambers can be seen clearly in thin sections and can be traced peripherally from the peripheral lip of the aperture for a short distance into the wall (Pl. 12, fig. 1). At about the point at which the boundary disappears in the illustration, in thin section the boundary can be seen to take a position at right angles to the surface of the wall. It then extends nearly to the outer surface in the new direction. A few thin laminae of calcite occur on the outer surface and seal the junction of the walls of adjacent chambers. In most instances that portion of the new chamber which overlaps some portion of the preceding chamber is added in such a manner that the structural features of the wall are continuous through both the wall of the old chamber and the overlapping wall of the new chamber. The wall structure in *Marginulinopsis* develops at right angles to the surface of the wall, and this structure is continuous if the new wall is added parallel to the preceding wall. The structure is not continuous in some cases where the new wall is added tangentially to the preceding wall.

The coiled series of *Marginulinopsis amplaspira* Young, n. sp., is illustrated in Plate 12, figure 2. The original wall of the proloculus is thin. As succeeding chambers are added the wall between any new chamber and the proloculus is thicker than the wall between the preceding chamber and the proloculus. The wall of the proloculus is thickened in successive chambers by the addition of calcite to the outer surface of the wall of the proloculus. However, the wall structures of the proloculus are not interrupted but continue through the added material. The proloculi of these forms of *Marginulinopsis* appear to have the same structures as the walls of the chambers. The wall between the proloculus and the first chamber is 6 microns thick in a specimen in which the inside diameter of the proloculus is about 85 microns. The thickness of the wall of the proloculus then increases as the succeeding chambers are added until the wall between the proloculus and the sixth chamber is about 30 microns thick.

Although I have carefully refrained from referring to the wall structures of *Marginulinopsis* as perforations, it seems evident that these structures are in reality the per-

* Xylene, kerosene, or other light hydrocarbons are satisfactory for this work. The specimen is mounted in a recessed (biological) slide with a cement which is not soluble in the hydrocarbon. The specimen is then completely immersed in liquid hydrocarbon. Studies may be made with both transmitted and reflected light. Photography is simplified because the focusing of the specimen is facilitated. Some effects are similar to those of dark field photography.

forations that were filled with calcite during fossilization. Examinations of fragments of wall from the chambers and examinations of thin-sections of *Marginulinopsis amplaspira* Young, n. sp., fail to reveal open pores even at magnifications as high as one thousand times.

MARGINULINOPSIS FRONTIERENSIS
Young, n. sp.
Plate 11, figures 9–12; figure 5—2–8

Test subconical to circular in peripheral outline, involute to the point of uncoiling, smooth, variable in size; keel rounded, frequently inconspicuous; earliest chambers involute, appressed; last two or three chambers evolute and even uncoiled; five to eight chambers in the outer whorl; last chamber may be slightly inflated; average test composed of the proloculus and from eight to fourteen chambers; sutures moderately curved proximally as they approach the periphery, not conspicuously limbate, rarely ornamented with small bosses, frequently flush with the surface of the test, extending peripherally from a large, slightly elevated, clear umbilical boss; aperture small, circular, located in a small knob at the junction of the last septal face with the periphery, pointing aperturoperipherally at an angle of about forty-five degrees to a tangent with the periphery at that point; maximum diameter 0.27 to 0.63 mm.; minimum diameter 0.21 to 0.42 mm.; dimensions in mm. as follows:

Specimen	*Diameter*		*Chambers in outer whorl*
	Maximum	*Minimum*	
holotype	0.48	0.36	8
paratypes	0.39	0.29	7
	0.42	0.29	7
	0.50	0.30	7
	0.57	0.32	8
	0.45	0.29	7
	0.51	0.31	7
	0.57	0.35	8
	0.63	0.42	7

Remarks.—*Marginulinopsis frontierensis*, n. sp., closely resembles some forms of *Marginulinopsis inconstantia* (Cushman), but is much smaller.

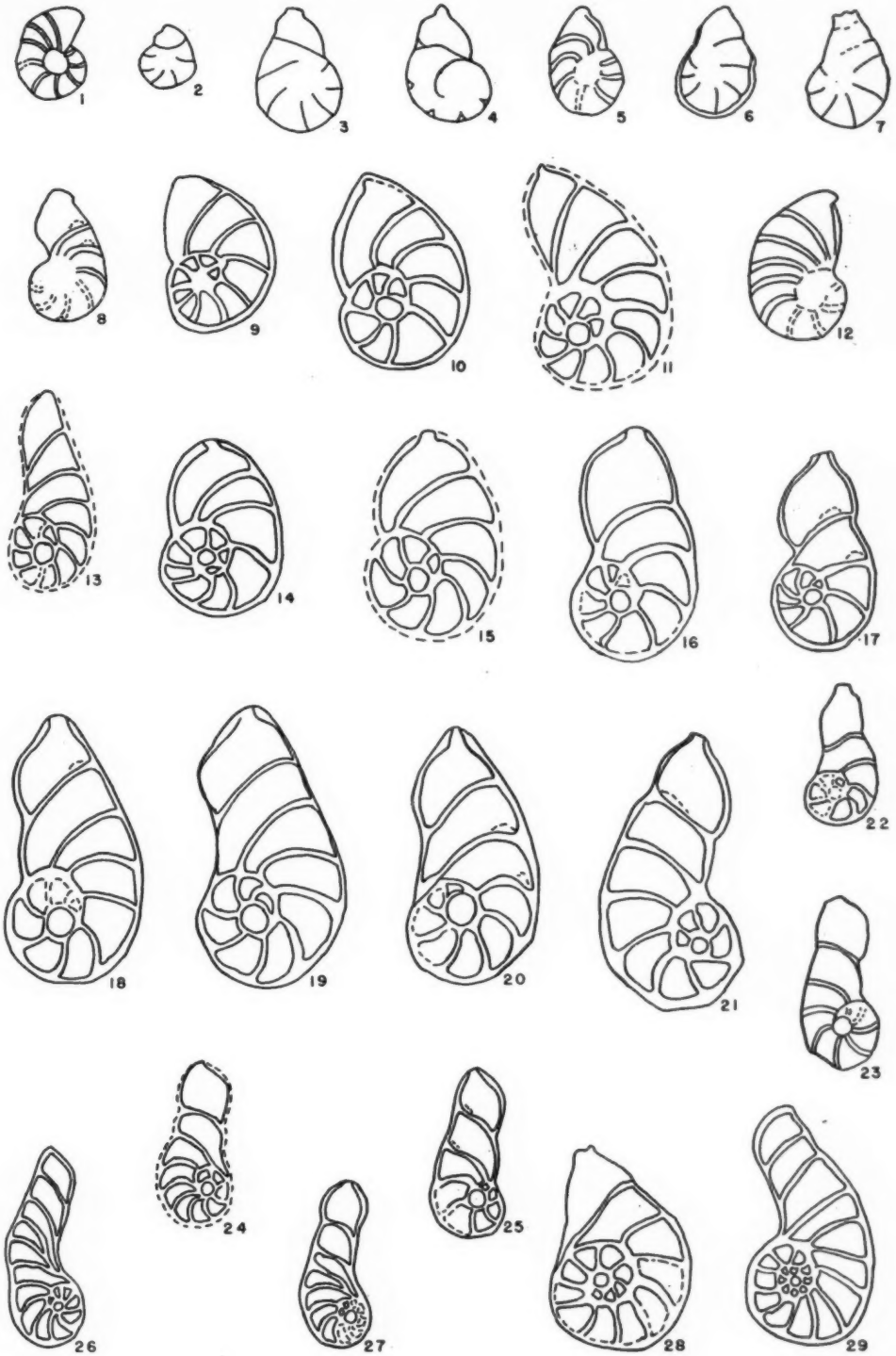
Occurrence.—*M. frontierensis* is common at four localities. The holotype and some paratypes are from a horizon 30 feet below the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2. Paratypes are also from 20 feet below the top of the "*Vascoceras* beds," Unit three, locality 1, horizon 1-b; 30 feet above the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 504, horizon 504-b; and from the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a.

Depository.—UW type collection, holotype, number 8; paratypes, number 9.

MARGINULINOPSIS AMMONITIFORMIS
Young, n. sp.
Plate 11, figures 22, 23; figure 5—9–12

Test involute to the point of uncoiling,

FIG. 5—Tracings of photographs of specimens in xylene.
1—*Lenticulina* n. sp. ×35; Locality 9b, horizon 9b-2.
2–8—*Marginulinopsis frontierensis* Young, n. sp. *3*, Holotype, ×45 (*See also* pl. 11, fig. 9); *2*, *4–8*, paratypes, ×45; *2* from locality 504, horizon 504-b; *3–8* from locality 9b, horizon 9b-2.
9–12—*Marginulinopsis ammonitiformis* Young, n. sp. *11*, Holotype, ×45 (*See also* pl. 11, figs. 22, 23); *9*, *10*, *12*, paratypes, ×45; *11* from locality 305, horizon 305-a; *9*, *10*, *12* from locality 1, horizon 1-b.
13—*Marginulinopsis* sp. This form may be a more adult stage of *M. ammonitiformis*, n. sp.; ×30; locality 305, horizon 305-a.
14–16, *18–21*—*Marginulinopsis amplaspira* Young, n. sp. *18*, Paratype, ×45 (*See also* pl. 11, figs. 15, 21); *21*, paratype, ×45 (*See also* pl. 11, fig. 18); *14–16*, *19*, *20*, paratypes, ×45; *14–16*, *18–20* from locality 305, horizon 305-a; *21* from locality 1, horizon 1-b.
17—Probably a variant of *M. amplaspira* Young, n. sp., ×45; only one specimen of this morphology was obtained from the collection; locality 305, horizon 305-a.
22—*Marginulinopsis* aff. *M. frontierensis* Young, n. sp., ×45; locality 9b, horizon 9b-2.
23–25—*Marginulinopsis amplaspira* Young, n. sp., ×30; locality 305, horizon 305-a.
26–27—*Marginulinopsis* sp. These specimens may or may not be pathologic; ×30; *26* from locality 504, horizon 504-b; *27* from locality 305, horizon 305-a.
28—*Marginulinopsis* sp. Specimen of unknown affinity, ×55; locality 305, horizon 305-a.
29—*Marginulinopsis* sp. ×30; locality 305, horizon 305-a.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increasing in size in a regular coil, smooth, with prominent keel; chambers closely appressed, overlapping at least to the umbilicus, eight to ten chambers in the outer volution; last chambers in the gerontic stage becoming evolute; chambers not inflated; test composed of the proloculus and from 10 to 13 chambers; sutures moderately curved proximally as they approach the periphery, often showing a slight limbateness in proper lighting; umbilical boss small, clear, frequently absent, never conspicuous, flush with the surface of the test when present; a small boss in each inter-sutural area about midway between the umbilicus and the periphery; aperture small, circular, at the periphery of the last septal face, occurring in a tubular thickening and enlargement of the keel; maximum diameter 0.60 to 0.70 mm.; minimum diameter 0.38 to 0.45 mm.; dimensions in mm. of five specimens as follows:

Specimen	*Diameter*		*No. of external chambers*
	Maximum	*Minimum*	
holotype	0.70	0.39	10
paratypes	0.68	0.45	8
	0.60	0.45	9
	0.63	0.38	8
	0.60	0.39	9

Remarks.—*Marginulinopsis ammonitiformis*, n. sp., is most distinctive in its manner of coiling and in the peripheral location of the circular aperture. It does not closely resemble previously described species.

Occurrence.—*M. ammonitiformis* is rare in the Frontier formation of southern Montana. The holotype and some paratypes were found in the "*Vascoceras* beds," Unit three, locality 305, horizon 305-a; and other paratypes were collected from 20 feet below the top of the "*Vascoceras* beds," Unit three, locality 1, horizon 1-b.

Depository.—UW type collection, holotype, number 10; paratypes, number 11.

MARGINULINOPSIS AMPLASPIRA Young, n. sp.

Plate 11, figures 15, 17–21; plate 12, figures 1–4, 6, 8–14; figure 5—14–16, 18–21; figure 6—2–16, 20

Test short to long, smooth; coiled series circular to polygonal in peripheral outline, many specimens with marked angles at the junctions of the sutures with the periphery; chambers in the coiled series closely appressed; uniserial series arcuate in the early portion, straight to arcuate in the later portion, the third, fourth, and fifth uniserial chambers when present usually not continuing the arcuate alignment; frequently a constriction in the earlier portion of the uniserial series produced by the inflation of the later chambers; first two chambers of the uniserial series closely appressed in specimens possessing more than three linear chambers, later chambers progressively more loosely joined; most proximal one or two sutures of linear series limbate when more than three chambers in the uniserial portion, otherwise sutures of the linear series depressed, slightly arcuate distally; umbilical boss raised, varying in size with the diameter of the coiled series; aperture radiate, protruding, and offset toward the periphery from the terminal center of the last chamber; aperture in many specimens migrating from the periphery toward a terminal condition in the linear series, but before obtaining a position terminal and central, migrating slightly toward the periphery again in the later portion of the

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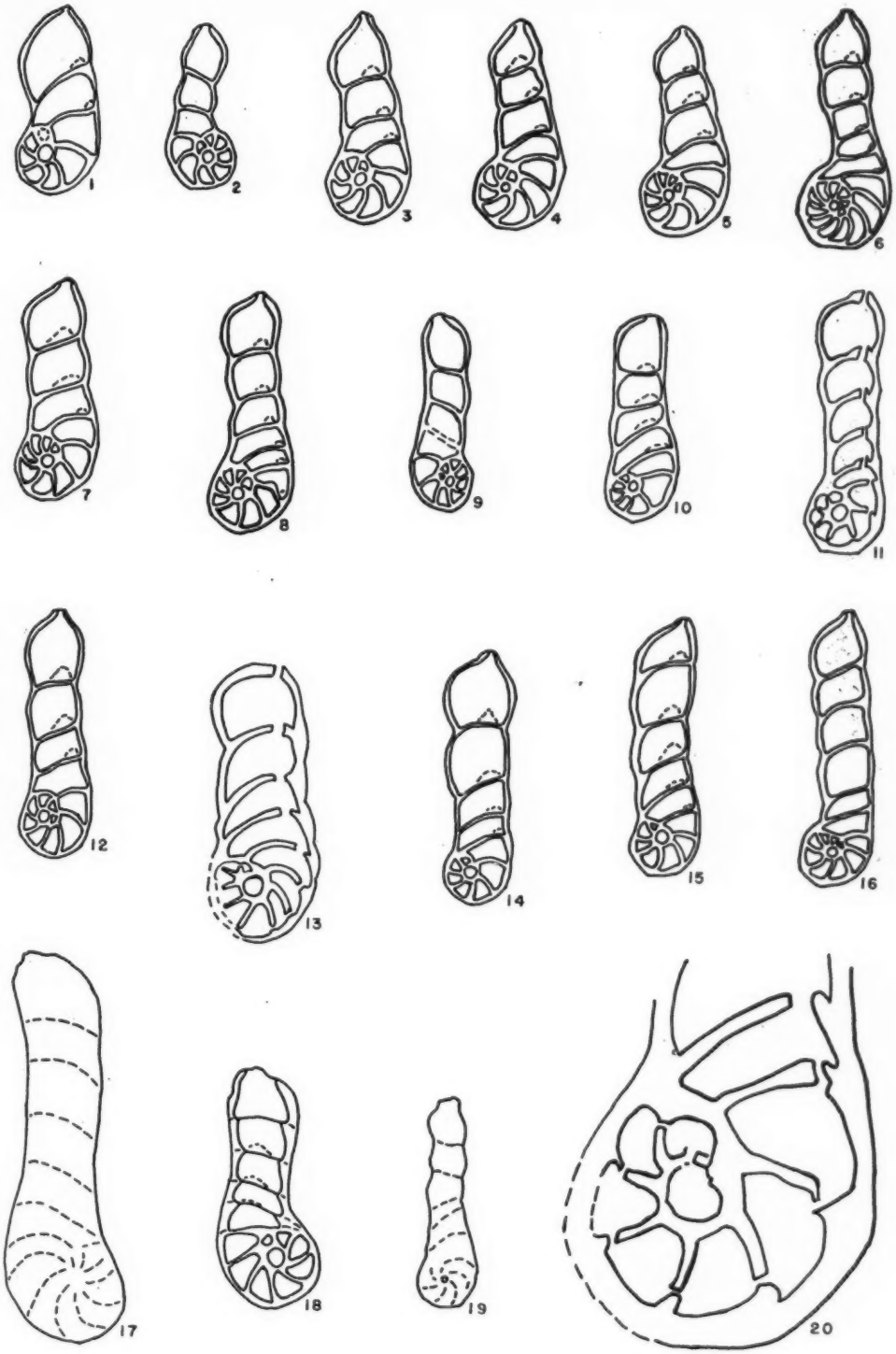
FIG. 6—All illustrations are traced from photographs of specimens in xylene except *11*, *13*, and *20*, which are tracings from photographs of thin sections.

1—*Marginulinopsis* n. sp. 3. ×45 (*See also* pl. 11, fig. 16 and pl. 12, fig. 7); locality 305, horizon 305-a.

2–16, *20*—*Marginulinopsis amplaspira* Young, n. sp. *6*, paratype, ×30 (*See also* pl. 12, fig. 12); *14*, holotype, ×30 (*See also* pl. 12, figs. 10, 11); *15*, paratype, ×30 (*See also* pl. 12, fig. 6); *11*, *20*, paratype, ×33 and ×180 (*See also* pl. 12, figs. 1–3); *2–5*, *7–10*, *12*, *16*, paratypes, ×30; *13*, paratype, ×40; *3–10*, *12*, *14–16* from locality 305, horizon 305-a; *2*, *11*, *13*, *20* from locality 1, horizon 1-b.

17, *18*—*Marginulinopsis* n. sp. 2. ×30; locality 1, horizon 1-b.

19—*Marginulinopsis* n. sp. 1. ×35 (*See also* pl. 12, fig. 5); locality 305, horizon 305-a.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uniserial series; length 0.65 to 1.45 mm.; dimensions in mm. as follows:

Specimen	*Length*	*Min. diameter of coiled series*	*Last chamber*		*No. of external chambers*
			Length	*Width*	
holotype	1.30	0.30	0.39	0.37	10
paratypes	0.78	0.39	0.24	0.29	8
	0.74	0.40	0.23	0.29	8
	0.65	0.33	0.24	0.24	8
	0.75	0.36	0.22	0.26	9
	0.79	0.35	0.24	0.26	9
	0.86	0.38	0.27	0.27	10
	0.94	0.38	0.21	0.24	11
	1.03	0.44	0.27	0.27	12
	1.15	0.39	0.26	0.30	10
	1.18	0.45	0.27	0.27	14
	1.21	0.42	0.24	0.29	14
	1.33	0.38	0.24	0.30	12
	1.40	0.39	0.44	0.41	11
	1.45	0.36	0.33	0.30	12

Remarks.—The analysis of the numerical data shows a rather continual gradation from one size ratio to the next, and there appear to be no discontinuities that would indicate the presence of microspheric and megalospheric forms. It is suggested that *Marginulinopsis* sp. (figure 5—28, 29) may represent the microspheric forms of this species. However, since other species of *Marginulinopsis* were obtained from the same sample, the evidence is not conclusive.

Marginulinopsis amplaspira, n. sp., is differentiated from *M. ammonitiformis*, n. sp., by the location and type of aperture and by the difference in coiling.

Occurrence.—*M. amplaspira* is one of the most abundant of the foraminiferal species in the Frontier formation of southern Montana. Some of the paratypes are from a horizon 30 feet below the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2; the holotype and other paratypes are from the "*Vascoceras* beds," Unit three, locality 305, horizon 305-a; other paratypes are from 30 feet above the base of the "*Vascoceras* beds," Unit three, locality 504, horizon 504-b; and from 20 feet below the top of the "*Vascoceras* beds," Unit

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EXPLANATION OF PLATE 13

FIGS. *1–3*—*Frondicularia frontierensis* Young, n. sp. *1*, Unretouched photograph of holotype in xylene with transmitted light, ×20; *2*, retouched photograph of paratype in xylene with transmitted light, ×20; *3*, retouched photograph of holotype in xylene with reflected light, ×28; *1, 3* from locality 305, horizon 305-a; *2* from locality 1, horizon 1-b. (p. 61)

4–6—*Frondicularia imbricata* Young, n. sp. *4*, Retouched photograph of holotype, ×55; *5*, retouched photograph of paratype, ×36; *6*, retouched photograph of weathered paratype, ×40; *4, 6* from locality 504, horizon 504-a; *5* from locality 1, horizon 1-a. (p. 61)

7, 8—*Frondicularia* n. sp. 1. *7*, Retouched photograph of specimen in xylene with transmitted light, ×47; *8*, retouched photograph of same specimen in xylene with reflected light, ×40; locality 9b, horizon 9b-2. (p. 62)

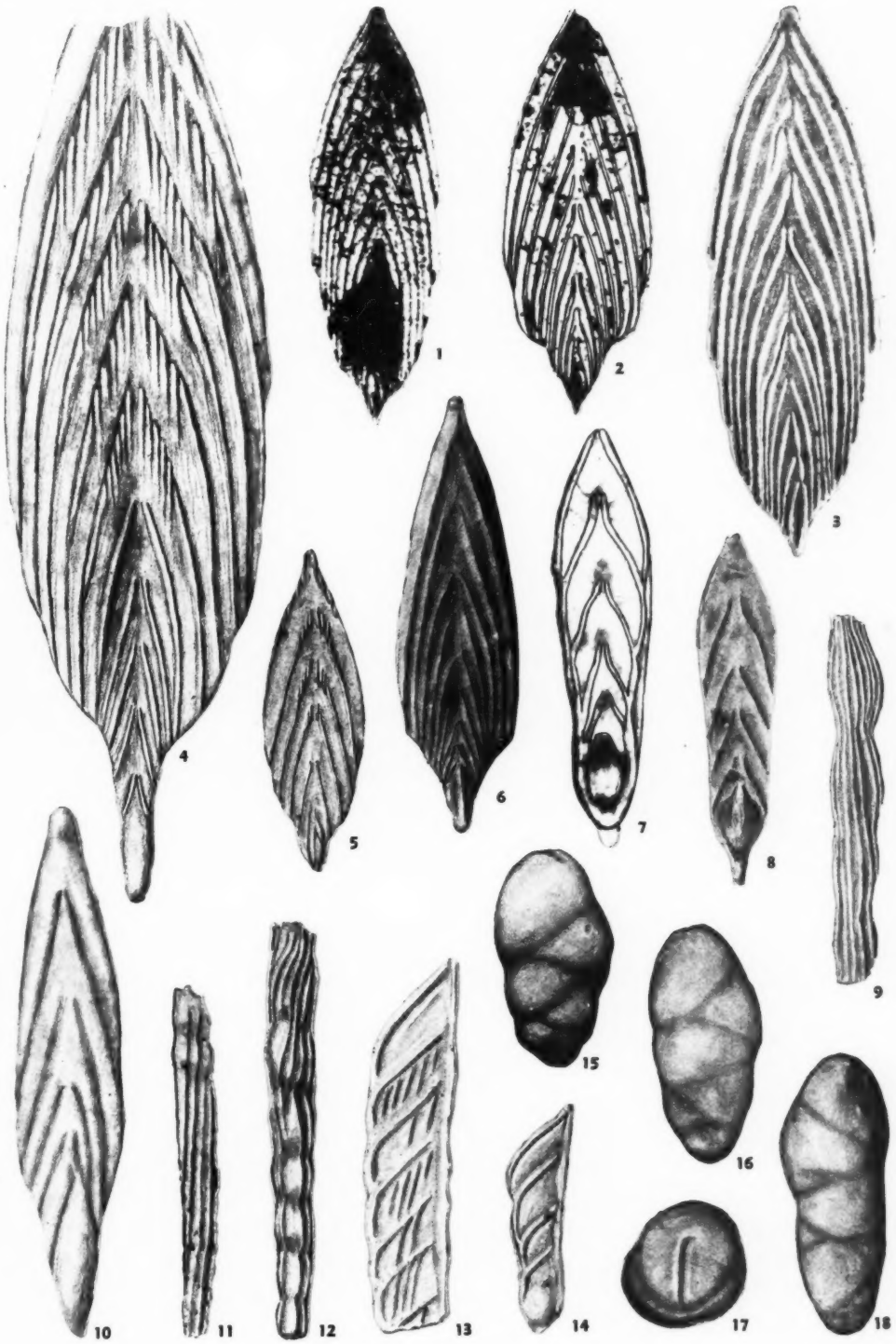
9—*Nodosaria* sp. 2. Retouched photograph of specimen from locality 305, horizon 305-a, ×55. (p. 60)

10—*Frondicularia* n. sp. 2. Retouched photograph of specimen from locality 504, horizon 504-a, ×90. (p. 62)

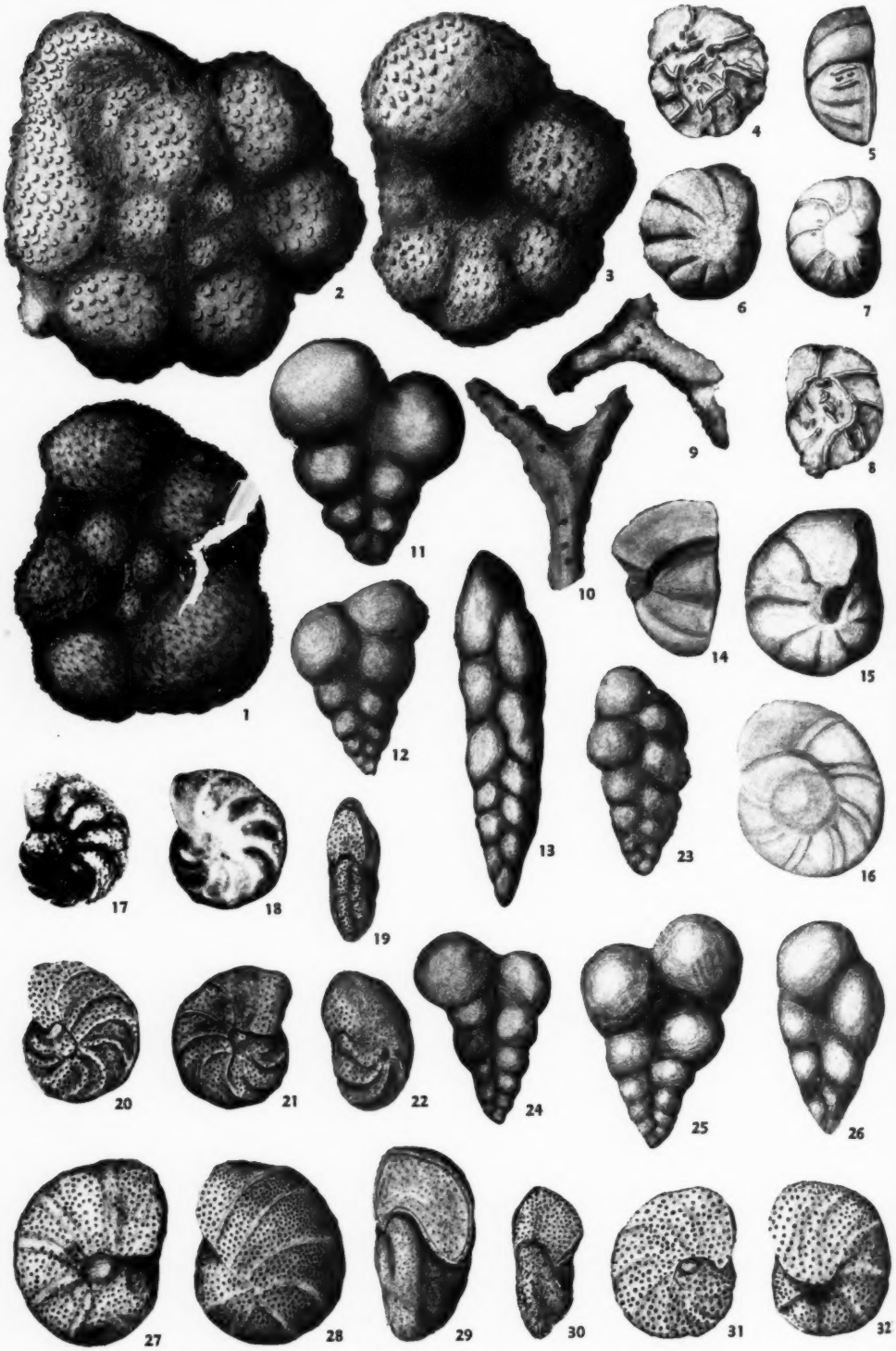
11, 12—*Nodosaria xavierensis* Young, n. sp. *12*, Holotype, ×55; *11*, paratype, ×55; both photographs retouched; both from locality 305, horizon 305-a. (p. 59)

13, 14—*Vaginulina* n. sp. *13*, ×40; *14*, ×45; both photographs retouched; both from locality 1, horizon 1-b. (p. 60)

15–18—*Bulimina bulletella* Young, n. sp. *16, 17*, Retouched photographs of apertural and lateral views of holotype, ×45; *15, 18*, retouched photographs of two paratypes, ×45; all from locality 9b, horizon 9b-2. (p. 64)



Young, Montana Frontier formation Foraminifera



Young, Montana Frontier formation Foraminifera

three, locality 1, horizon 1-b.

Depository.—UW type collection, holotype, number 17; paratypes, numbers 12–16, 18.

MARGINULINOPSIS n. sp. 1
Plate 12, figure 5; figure 6—19

Test long in relation to the size of the coiled series, coiled series circular in peripheral outline; five chambers in the linear series, seven or eight chambers in the coiled series with six chambers in the outer whorl; chambers in coiled series closely appressed, the first two chambers of the linear series appressed, the last three chambers of the linear series loosely joined; sutures of the coiled series limbate, though only slightly raised, one suture at the initial end of the linear series slightly limbate, remaining sutures of the linear series depressed, becoming more depressed as the chambers become more inflated and loosely joined; sutures of the coiled series arcuate and curved proximally as they approach the periphery of the test. The aperture of this specimen is extremely unusual, but may be pathologic, as only one specimen was available for study; the aperture occurs in a large, transversely elongated protuberance at the terminal end of the last chamber and consists of two adjacent radiate apertures in the one protuberance; length of test 0.85 mm.; minimum diameter of coiled series 0.24 mm.; length of last chamber 0.20 mm.; width of last chamber 0.19 mm.

Remarks.—Only one specimen of this form was found in the Frontier collection of southern Montana. It is quite distinct because it has a long tapering linear series and a relatively small coiled series.

Occurrence.—*Marginulinopsis* n. sp. 1 was found in the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a.

Depository.—UW type collection, number 19.

MARGINULINOPSIS n. sp. 2
Figure 6—17, 18

Test long, smooth, the linear series straight for several chambers and then curving toward the periphery; coiled series generally circular in peripheral outline with a well developed keel; nine chambers in the coiled series of the only specimen studied in xylene in which the number of chambers could be determined; at least six chambers in the linear series, chambers closely appressed throughout the test, external wall of cham-

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EXPLANATION OF PLATE 14

All illustrations on this plate are retouched photographs except figures *17* and *18*. Figures *17* and *18* are unretouched photographs.

FIGS. *1–3*—*Globigerina cretacea* d'Orbigny. Three specimens ×130; *1* from locality 305, horizon 305-a; *2* from locality 1, horizon 1-b; *3* from locality 9b, horizon 9b-1. (p. 65)

4–8—*Stensioina* n. sp. *4–6*, Dorsal, peripheral, and ventral views of one specimen, ×55; *7, 8*, dorsal and ventral views of another specimen, ×55; both from locality 9b, horizon 9b-2. (p. 65)

9, 10—*Ramulina* sp. Two specimens, ×55; *9* from locality 504, horizon 504-a; *10* from locality 1, horizon 1-a. (p. 62)

11—*Gümbelina* sp. Specimen from locality 504, horizon 504-a, ×170. (p. 63)

12, 23–26—*Gümbelina globulosa* (Ehrenberg). All ×170; *12, 23* from locality 305, horizon 305-a; *24, 26* from locality 504, horizon 504-a; *25* from locality 1, horizon 1-b; *23* represents Variant 2; *24* represents Variant 1. (p. 63)

13—*Loxostomum tegulatum* (Reuss). Specimen from locality 1, horizon 1-a, ×170. (p. 64)

14–16—*Gyroidina* n. sp. Peripheral, ventral, and dorsal views of one specimen from locality 9b, horizon 9b-2, ×70. (p. 65)

17–22—*Anomalina bighornensis* Young, n. sp. *19–21*, Peripheral, dorsal, and ventral views of holotype, ×45; *17*, unretouched photograph of holotype in xylene with transmitted light, ×45; *22*, ventro-peripheral view of paratype, ×45; *18*, unretouched dorsal view of holotype in xylene with reflected light, ×45; both specimens from locality 9b, horizon 9b-2. (p. 66)

27–29—*Cibicides kennedyi* Young, n. sp. Dorsal, ventral, and peripheral views of holotype, ×70; locality 9b, horizon 9b-2. (p. 66)

30–32—*Cibicides* n. sp. Peripheral, dorsal, and ventral views of specimen from locality 9b, horizon 9b-2, ×70. (p. 67)

bers much thicker than in other species of *Marginulinopsis* from this horizon and locality; chambers not inflated; frequently two or three small bosses in the umbilical region; sutures slightly limbate in the coiled series when viewed in oblique light, only slightly depressed in the linear series; aperture radiate and in a protuberance at the distal end of the last chamber, located about half way between the terminal center and the peripheral edge of the last chamber; dimensions of two specimens as follows: length 1.00 and 1.74 mm.; minimum diameter of coiled series 0.38 and 0.54 mm.

Remarks.—The distal portions of the linear series were broken on all of my specimens of *Marginulinopsis* n. sp. 2. This form can be distinguished from most species of *Marginulinopsis* by its strongly keeled coiled series, by the thick external walls of the chambers, and by the appressed attitude of the chambers throughout the linear series.

Occurrence.—A few specimens of *Marginulinopsis* n. sp. 2 were found at a horizon 20 feet below the top of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-b.

Depository.—UW type collection, number 20.

MARGINULINOPSIS n. sp. 3
Plate 11, figure 16; plate 12, figure 7; figure 6—1

Test small, smooth, with one linear chamber; coiled series subcircular in peripheral outline, relatively small; chambers expanding rapidly in size; last chamber slightly inflated, but not noticeably in the peripheral region, chambers all closely appressed, totaling 11; sutures not limbate, even under very oblique lighting, flush with the test, curving proximally as they approach the periphery; keel only slightly developed; umbilical boss minute; aperture small, radiate, slightly protruding, but not located in a raised protuberance, peripheral throughout the test; length 0.54 mm.; minimum diameter of coiled series 0.23 mm.; length of last chamber 0.18 mm.; width of last chamber 0.24 mm.

Remarks.—Only one specimen of *Marginulinopsis* n. sp. 3 was found in the Frontier formation of southern Montana. It does not resemble any of the other species from the Frontier formation of this area. It has very distinctive shape and manner of coiling.

Occurrence.—The one specimen of *Marginulinopsis* n. sp. 3 was found in the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a.

Depository.—UW type collection, number 21.

MARGINULINOPSIS sp.
Figure 5—24, 26, 29

Three specimens of *Marginulinopsis* that differ radically from the above forms were obtained from the "*Vascoceras* beds." Although the manner of coiling and general aspect of two of these specimens are somewhat similar to *Marginulinopsis amplaspira*, n. sp., the linear series are different. These specimens have a very characteristic arrangement of the linear sutures, but differ greatly in other characters. In all three specimens there is an overlap of one of the linear septa proximally over the other chambers to the coiled series on that edge opposite the periphery. Actually this overlap changes the direction of growth of the linear series (fig. 5—26). It cannot be determined if this character is pathologic. The three specimens differ in many other respects. For the sake of completeness they are all illustrated.

Occurrence.—The specimen illustrated in figure 5—29, was found in the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a. The specimens illustrated in figure 5—24 and 26 were found 30 feet above the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 504, horizon 504-b.

Genus NODOSARIA Lamarck 1812
NODOSARIA BIGHORNENSIS Young, n. sp.
Plate 12, figures 17, 19

Test straight to slightly curved, long, slender, containing an average of about eight chambers, ornamented with seven or eight raised costae that do not spiral around the test; costae first appearing just distal to the proximal spine, dying out on the last chamber, evenly spaced, consistent in size throughout their length, extending the full length of the test; intercostal areas very wide; chambers not inflated, uneven in length, inconspicuous externally; sutures may be depressed or may be invisible, very

uneven; proloculus usually possessing a greater diameter than the first chamber; last chamber tapering aperturally and drawn out into a long neck; aperture terminal in the neck, radiate; length from 0.54 to 1.12 mm.; dimensions in mm. as follows:

Specimen	*Length*	*Width*	*Width of proloculus*
holotype	1.01	0.15	0.08
figured paratype	0.66	0.12	0.06
unfigured paratypes	0.75	0.15	0.09
	0.60	0.13	0.06
	1.06+	0.17	broken
	0.54	0.12	broken
	1.12	0.13	0.08

Remarks.—*Nodosaria bighornensis*, n. sp., does not resemble closely any previously described forms. Its most distinctive characteristics are shape, consistency yet paucity of costae, and the broad intercostal areas.

Occurrence.—The holotype and some of the paratypes are from the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a; other paratypes are from 20 feet below the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-1; 30 feet above the base of the "*Vascoceras* beds," Unit three, locality 504, horizon 504-b; and from 20 feet below the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-b.

Depository.—UW type collection, holotype, number 22; paratypes, number 23.

NODOSARIA XAVIERENSIS
Young, n. sp.
Plate 12, figure 15; plate 13, figures 11, 12

Test straight, long, slender, composed of from five to ten chambers, ornamented with approximately four to eight raised costae that continue across the sutures and spiral around the test about one-half convolution in five chambers, varying in individuals; costae increasing in number by intercalation, more numerous and more crooked aperturally; chambers only slightly inflated, frequently indistinct unless filled with foreign material or studied in light hydrocarbons; sutures at right angles to the linear axis and represented by faint constrictions in the test; aperture radiate, terminal, located in a slight protuberance on the tapering distal end of the last chamber; dimensions in mm. as follows:

Specimen	*Length*	*Width*
holotype	1.13	0.14
paratypes	1.57	0.16
	1.18	0.15
	1.15	0.15

Remarks.—*Nodosaria xavierensis*, n. sp., can be distinguished from *N. bighornensis*, n. sp., by the spiralling of its costae and by the deeply depressed sutures. The neck is less distinct in *N. xavierensis* than in *N. bighornensis*.

Occurrence.—*N. xavierensis* is common in the collection from the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a.

Depository.—UW type collection, holotype, number 24; paratypes, number 25.

NODOSARIA sp. 1
Plate 12, figure 20

Test ornamented with large costae which extend for two or three chambers, spiral part way around the test and disappear; costae coarse, continuing straight for the length of one or two chambers before suddenly curving, always clockwise as viewed from the proximal end; chambers inflated with concurrent depressions revealing the sutures; chambers variable in length; aperture terminal at the tapering distal end of the last chamber; diameters of a number of chambers in different specimens are as follows: 0.21, 0.24, 0.30, 0.33, 0.38 mm.

Remarks.—A large number of fragments of *Nodosaria* sp. 1 were found at two localities. The great diameter of the chambers indicates that the species is large. It may belong to the genus *Dentalina* d'Orbigny, but the fragmental condition of the specimens makes a definite generic assignment difficult. In no specimens could more than four chambers be observed intact.

Occurrence.—*Nodosaria* sp. 1 is common in the collections from the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a; and from strata 20 feet below the top of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-b.

Depository.—UW type collection, number 26.

NODOSARIA sp. 2
Plate 13, figure 9

Test straight, long, slender, the number of chambers unknown, ornamented with approximately 15 costae which may or may not extend the length of the test, but many of which extend for two or three chambers and then disappear. Costae intercalated, closely spaced, dying out altogether on the apertural half of the last chamber, spiralling slightly around the test about 30 degrees in four chambers; chambers inflated, length-width ratio of chambers increasing apertural, later chambers almost twice as long as wide; sutures broadly depressed at right angles to the linear axis; proloculus unknown; aperture terminal, radiate, located at the tapering distal end of the last chamber; no neck.

Remarks.—*Nodosaria* sp. 2 has the same general appearance as *Dentalina angusticostata* Cushman (Cushman, 1946). However, *Nodosaria* sp. 2 is not heavily costated on the apertural half of the last chamber and the neck is not developed. All of the specimens from the Frontier formation of southern Montana are fragmental.

Occurrence.—*Nodosaria* sp. 2 is common in the collections from the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a; and from strata 20 feet below the top of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-b.

Depository.—UW type collection, number 27.

NODOSARIA ? sp. 3
Plate 12, figures 16, 18

Test arcuate in early portion, increasing regularly in size, later portion unknown; costae closely spaced, spiralling around the test one-half convolution in about four chambers, increasing in number by intercalation, beginning at and extending from just distal to a proximal spine; chambers uneven in size and spacing, slightly inflated; sutures definite and depressed; aperture unknown.

Remarks.—Two fragmental specimens here described as *Nodosaria* ? sp. 3 are questionably referred to *Nodosaria*, although they may belong to the genus *Dentalina* d'Orbigny. These specimens seem distinct from other forms of this fauna, but only two proximal fragments were collected. They are distinguished from *Nodosaria* sp. 1 by the manner of spiralling of the costae and by the sutural depressions. However, as no proximal fragments of *Nodosaria* sp. 1 have been observed, it is not possible to determine definitely that these fragments do not represent the proximal portions of *Nodosaria* sp. 1.

Occurrence.—The two specimens were found 20 feet below the top of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-b.

Depository.—UW type collection, number 28.

Genus VAGINULINA
d'Orbigny 1826
VAGINULINA n. sp.
Plate 13, figures 13, 14

Test long, narrow, calcareous, perforate, not compressed, slightly wider toward the apertural end, widening most rapidly during the first few chambers; peripheral and lateral margins truncated; proloculus large, inflated, somewhat lagenid, but unevenly so; later chambers added evenly, flat-sided, distinct, not overlapping the peripherolateral margin of the preceding chamber; sutures distinct, sigmoid, limbate; chambers ornamented with from one to five fine striae that start with the last formed suture and extend proximally and slightly laterally almost to or to the preceding suture; aperture radiate, in a short indistinct terminal neck; the proloculus of the specimen illustrated (Plate 13, figure 14) is 0.18 mm. long and 0.12 mm. wide; maximum widths of several specimens as follows: 0.21, 0.30, 0.21, 0.27, 0.21, 0.27, 0.31, 0.24, and 0.27 mm.

Remarks.—All specimens of *Vaginulina* n. sp. are fragmental. These specimens are best characterized by their simplicity of shape and in the absence of proximal overlap of more distal chambers along the lateral margins.

Occurrence.—*Vaginulina* n. sp. is rare in the Frontier formation of southern Montana. It occurs in the "*Vascoceras* beds," Unit three, locality 305, horizon 305-a;

in strata 30 feet above the base of the "*Vascoceras* beds," Unit three, locality 504, horizon 504-b; and in strata 20 feet below the top of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-b.

Depository.—UW type collection, number 29.

Genus FRONDICULARIA
Defrance 1826

FRONDICULARIA IMBRICATA
Young, n. sp.
Plate 13, figures 4–6

Test calcareous, perforate, thin, elongate, variable in general outline, but as a rule broadly oval to wedgeshaped; proloculus elongate, often protruding proximally beyond the chambers, some specimens indicating coiled ancestry by the uneven addition of the second and third chambers; later chambers added evenly and regularly in normal specimens; sutures slightly limbate in unweathered specimens, but the limbate sutures are frequently eroded; sutures normal and single up to about the fourth to sixth chamber; distal to the fourth, fifth, or sixth chambers the proximal portions of the sutures are normal and single, the distal portions of the sutures consisting of successive layers of limbate suture overlapped peripherally by preceding layers to form an imbricate pattern of the limbate sutures in the distal portions of the later chambers; proximal extension of the chambers dependent on the specimen and the amount of erosion that has occurred; apertural end of chamber projected aperturally to form a definite neck containing the terminal, radiate aperture; dimensions in mm. as follows:

Specimen	*Length*	*Width*	*Proloculus*	
			Length	*Width*
holotype	1.78+	0.60	0.21	0.07
figured paratype	0.89	0.34	0.24	0.06
figured paratype	1.51	0.42	0.22	0.08
paratypes	0.82	0.24	0.22	0.06
	2.26+	0.63	broken.....	
	1.40+	0.34	broken.....	
	1.35	0.36	0.24	0.05
	1.18	0.31	0.25	0.09
	1.34	0.42	0.27	0.07
	1.51	0.42	0.27	0.08

Remarks.—*Frondicularia imbricata*, n. sp., is most easily distinguished from closely similar forms by the surface ornamentation. Also, its shape and the manner in which the later chambers overlap the lateral margins of the earlier chambers distinguish it from *F. frontierensis*, n. sp.

Occurrence.—*Frondicularia imbricata*, n. sp., is common in two localities of the upper Frontier formation of southern Montana. The holotype and some of the paratypes are from the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 504, horizon 504-a; other paratypes are from the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-b.

Depository.—UW type collection, holotype, number 32; paratypes, number 33.

FRONDICULARIA FRONTIERENSIS
Young, n. sp.
Plate 13, figures 1–3

Test calcareous, perforate, thin, elongate, typically lance-shaped, as in the holotype; first two chambers normally added aperturo-laterally on one and the same side, as in *Vaginulina;* later chambers normally added evenly and symmetrically, frequently extended proximally to cause the specimen to appear slightly wedge-shaped; 10 to 14 chambers in the normal adult; holotype shows abnormal addition of the fifth, sixth and tenth chambers (Pl. 13, figures 1, 3); sutures slightly limbate; distal portion of chambers protruding to form a short neck containing the terminal, radiate aperture; dimensions in mm. as follows:

Specimen	*Length*	*Width*	*Proloculus*	
			Length	*Width*
holotype	2.24	0.71	0.18	0.06
figured paratype	1.74	0.64	0.15	0.06
paratypes	broken	0.70	0.24	0.06
	1.66	0.66	0.18	0.07

Remarks.—*Frondicularia frontierensis*, n. sp., is distinguished from *F. imbricata*, n. sp., by its lack of distinctive ornamentation, by the more even width of its chambers, by its shape, and by the greater proximal overlap of its later chambers.

Occurrence.—*F. frontierensis* is not common in the Frontier formation of southern

Montana. The holotype and two paratypes are from the "*Vascoceras* beds," Unit three of the Frontier formation, locality 305, horizon 305-a; the other paratypes are from the top and the base of the "*Vascoceras* beds," Unit three, locality 1, horizons 1-a and 1-c, and from 30 feet above the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 504, horizon 504-b.

Depository.—UW type collection, holotype, number 30; paratypes, number 31.

FRONDICULARIA n. sp. 1
Plate 13, figures 7, 8

Test elongate, symmetrical, with proximal spine on the proloculus; proloculus large, spherical, lagenid; chambers subsequent to the proloculus added uniserially, enlarging distally, the single specimen having, in addition to the proloculus, five chambers; chambers not overlapping the peripheral margins except distally; peripheral margin definitely truncated except in the region of the proloculus; sutures limbate, sloping away from the linear axis proximally; neck apertural, small; aperture terminal, radiate; dimensions in mm. as follows: length 1.04 mm.; width 0.24 mm.; length of proloculus 0.28 mm.; width of proloculus 0.18 mm.

Remarks.—The single specimen of *Frondicularia* n. sp. 1 represents the only form, known to the author, of *Frondicularia* from the Frontier formation in southern Montana that has the lagenid type proloculus. It is very similar to the specimens of *F. linearis* Franke from the Annona chalk illustrated by Cushman (1946). These forms may prove to be conspecific.

Occurrence.—*Frondicularia* n. sp. 1 is from a horizon about 30 feet below the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, number 34.

FRONDICULARIA n. sp. 2
Plate 13, figure 10

Test small, calcareous, perforate, elongate; proloculus elongate, protruding proximally from the later chambers; second and third chambers added irregularly, third chamber overlapping the second on the concave side, fourth chamber overlapping the third chamber laterally, but not proximally, fifth and sixth chambers added evenly and symmetrically, not overlapping the lateral margins; chambers inflated, sutures depressed with a slight limbate wall lying within the depression; chambers protruding aperturally to form a definite neck containing the terminal, radiate aperture; dimensions in mm. as follows: length 0.68; width 0.17; length of proloculus 0.18; width of proloculus 0.07.

Remarks.—*Frondicularia* n. sp. 2 has many features similar to *F. frontierensis*, n. sp. Its manner of growth is similar. However, the general shape, the smaller size at a comparable stage of growth, the failure of later chambers to overlap the lateral margins of the earlier chambers, and the inflation of the chambers distinguish this specimen from *F. frontierensis*, n. sp., and it seems very improbable that this specimen is a juvenile of *F. frontierensis*, n. sp.

Occurrence.—The specimen of *Frondicularia* n. sp. 2 is from the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 504, horizon 504-a.

Depository.—UW type collection, number 35.

Family POLYMORPHINIDAE
Genus RAMULINA
Jones 1875
RAMULINA sp.
Plate 14, figures 9, 10

Two broken specimens of a form similar to *Ramulina arkadelphiana* Cushman were recovered from the Frontier collection. Test irregularly elongate, branched portions with tapering tubular projections extending in different directions; from these irregular branches extend further projections with tapering distal portions; test finely and sparsely hispid; aperture small, circular, located in the distal ends of the tapering projections.

Occurrence.—*Ramulina* sp. is rare in the Frontier formation of southern Montana. One specimen was found 30 feet above the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 504, horizon 504-b, and another specimen was found in the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-a.

Depository.—UW type collection, number 37.

Family HETEROHELICIDAE
Genus GÜMBELINA
Egger 1899
GÜMBELINA GLOBULOSA
(Ehrenberg 1839)
Plate 14, figures 12, 23–26

Test rapidly expanding from the acute initial end to the widest portion formed by the last two chambers or the two chambers next to the last, coiled in the earliest stage of the microspheric form, but not always obviously so, especially in weathered specimens; later portion biserial, widest near the apertural end; chambers inflated, globular, increasing rapidly in size; sutures depressed, distinct, approaching the linear axis at or nearly at right angles; aperture large, medianal, highly arched, at the base of the last septal face.

Variant 1.—The specimens referred above to *Gümbelina globulosa* (Ehrenberg) are similar to the specimens here referred to as variant 1, except for the last chamber. The last biserial chamber of variant 1 is much enlarged, inflated, and dislocated. Except for this enlargement, the last chamber retains a normal position. The last chamber therefore protrudes over an imaginary extension of the lateral margin of the earlier chambers on one side.

Variant 2.—Specimens of this morphological variant develop in a manner normal to the species except that the last chamber is terminal and central between the last two biserial chambers. No specimen has been observed with further uniserial development beyond this one-chamber stage.

Remarks.—*Gümbelina globulosa* (Ehrenberg) is almost universally distributed in Upper Cretaceous rocks of ages similar to that of the Frontier formation. It has been reported from the Niobrara formation by Loetterle (1937); from the Greenhorn limestone, the Carlile shale, and the Niobrara formation by Morrow (1934); and from the Niobrara formation of southeastern Wyoming by Carman (1929). This species is present in all of the upper Frontier foraminiferal-bearing collections from southern Montana. Many of the specimens from the Frontier show marked morphologic variation. *G. globulosa* (Ehrenberg) has had a large number of morphologic variants assigned to it in the literature. Thus three or more morphologic types may appear illustrated under this name. On the other hand, in the Frontier formation of southern Montana three morphologic types, two of which are considered as morphologic variants in this paper, occur together in about equal abundance. They differ generally in the location and size of the last chamber. A few intergradational forms are present, and it seems most likely that the species is highly variable and contains at least three morphologic types.

Occurrence.—*Gümbelina globulosa* (Ehrenberg) is widespread through the Frontier formation of southern Montana. Specimens were found at the top, from 20 feet below the top, and from the base of the "*Vascoceras* beds," Unit three, locality 1, horizons 1-a, 1-b, and 1-c; in the base and 30 feet above the base of the "*Vascoceras* beds," Unit three, locality 504, horizons 504-a and 504-b; in the "*Vascoceras* beds," Unit three, locality 305, horizon 305–a; and from 20 feet below and 30 feet below the base of the "*Vascoceras* beds," Unit two of the Frontier formation, locality 9b, horizons 9b-1 and 9b-2.

Depository.—UW type collection, number 38.

GÜMBELINA sp.
Plate 14, figure 11

Test smooth, coiled in the earlier stage of the microspheric form, later biserial, very wide at the apertural end and tapering rapidly toward the proximal end; width of test at the apertural end almost equal to the length of the test; chambers expanding rapidly in size as added, highly inflated; sutures deeply depressed, distinct, entering the linear axis at or nearly at right angles, the intersections of the sutures forming definite triangular indentations between any three chambers; aperture large, low, arched at the medianal base of the last chamber; dimensions in mm. as follows:

Length	*Width*	*Diameter of last chamber*	*Diameter of penultimate chamber*
0.27	0.23	0.14	0.12
0.26	0.24	0.15	0.13

Remarks.—My collections contain only two specimens of *Gümbelina* sp. They are characterized by their small number of chambers and their length-width ratio of about unit value.

Occurrence.—The two specimens of *Gümbelina* sp. are from the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 504, horizon 504-a.

Depository.—UW type collection, number 39.

Family BULIMINIDAE
Genus BULIMINA
d'Orbigny 1826
BULIMINA BULLETELLA
Young, n. sp.
Plate 13, figures 15–18

Test an elongated egg in outline, greatest width near the aperture, smooth, length two to two and one-half times the width, consisting of from three to five whorls; chambers numerous, indistinct, slightly inflated; last two sutures slightly depressed, but position of earlier sutures determined only by studying specimens in light hydrocarbons; sutures locally flush, but appearing broadly depressed because of the inflation of the chambers; aperture a curved slit with the base of the slit at the base of the last septal face and the hook of the curve near the apex of the last chamber; teeth absent or concealed by the secondary filling of the aperture; dimensions in mm. as follows:

Specimen	*Length*	*Width*
holotype	0.76	0.36
paratypes	0.57	0.30
	0.86	0.34

Remarks.—*Bulimina bulletella*, n. sp., more closely resembles *B. aspera* Cushman and Parker than other species of this genus. However, *B. bulletella* has fewer chambers and is more consistent in width, tapering more rapidly at the proximal end of the test. The two species are of similar size.

Occurrence.—*B. bulletella* is rare in the Frontier formation of southern Montana. It was found at one locality about 30 feet below the "*Vascoceras* beds," Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, holotype, number 40; paratypes, number 41.

Genus LOXOSTOMUM
Ehrenberg 1854
LOXOSTOMUM TEGULATUM
(Reuss 1854)
Plate 14, figure 13

Test elongate, slender, gently tapering, tapering more rapidly toward the proximal end, biserial; chambers numerous, only slightly inflated, sufficiently appressed to be polyhedral in plan view, depending on the form of the earlier chambers; sutures distinct, depressed, approaching the linear axis at nearly right angles; aperture an elongate, almost terminal, oval slit extending distally from about halfway between the base of the last chamber and the terminal end; dimensions in mm. as follows:

Length	*Width*	*Thickness*
0.47	0.11	0.08
0.39	0.12	0.07
0.36	0.12	0.07
0.39	0.12	0.07

Remarks.—*Loxostomum tegulatum* (Reuss) is common in many of the formations of Colorado age. It is more closely similar to *L. plaitum* (Carsey) than to any other forms. It can be easily distinguished from *L. plaitum* (Carsey) by its different sutural pattern. Of the entire Frontier microfauna, specimens of *L. tegulatum* (Reuss) are the only ones in which the tests seem to be greatly altered. The specimens of this species appear to have been filled with some sideritic or pyritic material that has since been at least partially oxidized, obtaining a red coloration. The fossils consist of these dark reddish-brown internal molds.

Occurrence.—*L. tegulatum* (Reuss) was found in the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 504, horizon 504-a; in strata 30 feet above the base of the "*Vascoceras* beds," Unit three, locality 504, horizon 504-b; and in the base of the "*Vascoceras* beds," Unit three of the Frontier formation, locality 1, horizon 1-a.

Depository.—UW type collection, number 42.

Family ROTALIIDAE
Genus GYROIDINA
d'Orbigny 1826
GYROIDINA n. sp.
Plate 14, figures 14–16

Test small, circular in peripheral outline, planoconvex, composed of about two convolutions; periphery rounded except on the acute dorso-peripheral edge, not keeled; dorsal side flat, not involute, innermost convolution raised and bossed; ventral side highly convex, hemispherical in shape, involute; umbilicus small, excavated on the ventral side; seven to eight chambers visible in the outer whorl; dorsal sutures indistinct and slightly depressed as they join the depressed spiral suture in the outer volution, ventral sutures depressed, producing a radiate pattern in lateral view; aperture a narrow slit extending from the periphery to the ventral umiblicus; dimensions in mm. as follows: diameter, 0.33 and 0.30; thickness, 0.24 and 0.23.

Remarks.—*Gyroidina* n. sp. compares favorably with specimens from the Fort Hays limestone described as *G. nitida* (Reuss) by Loetterle (1937). However, the Frontier species has almost twice as many chambers in the outer convolution as the species described by Loetterle, and it also slopes less rapidly from the periphery to the ventral umbilicus.

Occurrence.—The two specimens of *Gyroidina* n. sp. were found 30 feet below the base of the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, number 43.

Genus STENSIOINA
Brotzen 1936
STENSIOINA n. sp.
Plate 14, figures 4–8

Test small, trochoid, planoconvex; dorsal side flat, almost completely involute, subcircular in peripheral outline; ventral side highly convex, completely involute, hemispherical in shape; peripheral margin sharp, but approaching an angle of ninety degrees, keeled with the keel directed peripherodorsally; ventral umbilical area filled and smooth; chambers distinct on the ventral side, indistinct on the dorsal side, nine to ten chambers in the outer volution; dorsal sutures distinct, raised, earlier dorsal sutures either partially resorbed or concealed, dorsal spiral suture shown by a raised suture which proximally becomes intermittent and still more proximally becomes a series of four or five small bosses; ventral sutures distinct and depressed with a small raised element in the center of the depressed suture in some specimens; dorsal side roughened, ventral side obviously perforate and less roughened; aperture a low arched opening ventral to the keel, but not extending to the umbilicus; dimensions in mm. as follows: diameter, 0.37 and 0.32; thickness, 0.21 and 0.18.

Remarks.—*Stensioina* n. sp. is smaller than *S. excolata* (Cushman). It resembles more closely *S. americana* Cushman and Dorsey. However, it differs from the latter in the absence of the concavity on the dorsal surface. The width-diameter ratio of *Stensioina* n. sp. is greater than that of *S. americana*. The umbilicus is more distinct in *S. americana* than in *Stensioina* n. sp.

Occurrence.—The two specimens of *Stensioina* n. sp. are from 30 feet below the "*Vascoceras* beds," in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, number 44.

Family GLOBIGERINIDAE
Genus GLOBIGERINA
d'Orbigny 1826
GLOBIGERINA CRETACEA
d'Orbigny 1826
Plate 14, figures 1–3

Test open, not compact, chambers loosely joined in a low trochoid spire, consisting of two to two and one-half volutions; chambers globular, inflated, averaging about five in number in the outer whorl, but may vary from four and one-half to six in the forms from the Frontier formation; sutures correspondingly deeply depressed; surface conspicuously hispid with the minute spines being worn off or dissolved through the action of surface waters in many specimens; aperture a large, arched orifice opening into the umbilicus; diameters of three adult specimens: 0.45, 0.42, and 0.42 mm.

Remarks.—The specimens of *Globigerina cretacea* from the Frontier formation of

southern Montana seem typical of the species. However, there are a large number of intergradational suites of specimens of this group that need further study. The secondary plate-like extensions of the chambers into the umbilicus described by Loeterle (1937) cannot be seen in the Frontier specimens. It is not known if these are characteristic of the species.

Occurrence.—*G. cretacea* d'Orbigny is very common in the upper Frontier formation at all horizons and at all localities from which foraminifers were obtained. It makes up about five per cent of the faunas from 20 feet and 30 feet below the "*Vascoceras* beds" in Unit two, locality 9b, horizons 9b-1 and 9b-2; about thirty-two per cent of the fauna from the base of the "*Vascoceras* beds," Unit three, locality 504, horizon 504-a; about fifty per cent of the fauna from 30 feet above the base of the "*Vascoceras* beds," Unit three, locality 504, horizon 504-b; about seventeen per cent of the fauna from the "*Vascoceras* beds," Unit three, locality 305, horizon 305-a; and about sixty-six per cent of the fauna from the base of the "*Vascoceras* beds," Unit three, locality 1, horizon 1-a.

Depository.—UW type collection, number 45.

Family ANOMALINIDAE
Genus ANOMALINA
d'Orbigny 1826
ANOMALINA BIGHORNENSIS
Young, n. sp.
Plate 14, figures 17–22

Test nearly circular in peripheral outline, biconvex, very coarsely perforate, dorsal and ventral faces equally convex, umbilical areas flattened, involute ventrally and dorsally, broadly rounded peripherally with a superimposed, broadly rounded, open keel; chambers numbering eight to ten in the outer volution, uninflated; sutures dorsally and ventrally limbate, arcuate distally, strongly curved, especially near the periphery; umbilicus a clear raised boss ventrally and dorsally, the ventral boss being larger; aperture a low, arched orifice at the base of the septal face over the periphery and extending as a narrow slit ventrally about halfway toward the umbilicus from the periphery; average diameter about 0.45 mm.; dimensions in mm. as follows:

Specimen	*Diameter*		*Thickness*
	Maximum	*Minimum*	
holotype	0.45	0.34	0.18
paratypes	0.48	0.38	0.19
	0.43	0.34	0.17
	0.39	0.34	0.18
	0.44	0.36	0.19

Remarks.—*Anomalina bighornensis*, n. sp., has been identified from one locality. However, rare crushed unidentifiable anomalinids were found at two other localities. This species has the general appearance of *Anomalina henbesti* Plummer, but the Frontier species has fewer chambers in the outer volution, and the chambers are wider.

Occurrence.—*A. bighornensis* was found 30 feet below the base of the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, holotype, number 46; paratypes, number 47.

Genus CIBICIDES Montfort 1808
CIBICIDES KENNEDYI
Young, n. sp.
Plate 14, figures 27–29

Test circular in peripheral outline, planoconvex, dorsal face flattened, ventral face highly rounded, test very coarsely perforate, involute to the umbilicus dorsally, much more involute ventrally, broadly rounded periphero-ventrally; dorso-peripheral junction angular; greatest thickness through the umbilicus; approximately eight to nine chambers in the outer volution in the adult; chambers slightly inflated; sutures limbate in early stages, becoming depressed in later stages, intermediately depressed over the periphery and limbate toward the umbilicus, moderately curved proximally as they approach the periphery, curvature more marked in some specimens than in others; umbilical boss large and clear dorsally, absent ventrally; aperture a narrow slit extending from the periphery dorsally almost to the umbilicus, not readily visible; dimensions in mm. as follows:

Specimen	Diameter		Thickness
	Maximum	Minimum	
holotype	0.38	0.30	0.21
paratypes	0.35	0.30	0.21
	0.36	0.28	0.21
	0.40	0.32	0.22
	0.34	0.30	0.21
	0.33	0.28	0.18

Remarks.—*Cibicides kennedyi*, n. sp., is distinguished by the coarseness of the perforations and by its great thickness.

Occurrence.—*C. kennedyi* was found only in Unit two of the Frontier formation of southern Montana at a horizon 30 feet below the base of the "*Vascoceras* beds," locality 9b, horizon 9b-2.

Depository.—UW type collection, holotype, number 48; paratypes, number 49.

CIBICIDES n. sp.
Plate 14, figures 30–32

Test circular in peripheral outline, planoconvex, very coarsely perforate, dorsal side flattened, ventral face moderately rounded, involute to the umbilicus dorsally, more involute ventrally, greatest thickness peripheral to the umbilicus, broadly rounded over the periphery; seven chambers in the outer volution, chambers not inflated; sutures faintly limbate throughout if viewed under very oblique light, moderately curved proximally as they approach the periphery; dorsal umbilical boss small, clear; umbilical boss absent ventrally; aperture a narrow slit extending from the periphery dorsally almost to the umbilicus, not readily visible; dimensions as follows: maximum diameter 0.29 mm.; minimum diameter 0.23 mm.; thickness 0.15 mm.

Remarks.—*Cibicides* n. sp. can be readily distinguished from *C. kennedyi*, n. sp., because its greatest thickness is peripheral to the umbilicus whereas that of *C. kennedyi* is greatest at the umbilicus. This results in an altogether different transverse section for *Cibicides* n. sp. than for *C. kennedyi*. None of the described Cretaceous species of *Cibicides* appear to be closely allied to either of the Frontier species.

Occurrence.—One specimen of *Cibicides* n. sp. occurs in the collection from a horizon 30 feet below the base of the "*Vascoceras* beds" in Unit two of the Frontier formation, locality 9b, horizon 9b-2.

Depository.—UW type collection, number 50.

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BRACHIOPODS OF THE HENRYHOUSE FORMATION (SILURIAN) OF OKLAHOMA[1]

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ABSTRACT—United States National Museum collections of brachiopods from the Henryhouse formation have furnished the material for this study. Forty-one species of brachiopods are described in this report, of which 25 are new; these are distributed through 27 genera. This fauna is similar to that found in the Brownsport formation of western Tennessee, and the two formations are believed to be of the same age.

DURING the field seasons of 1941 and 1947, Dr. G. A. Cooper made fossil collections from the Henryhouse formation of central Oklahoma. Extensive additions were made to these collections by Drs. A. R. Loeblich, Jr., and William Ham in the summer of 1947. At the suggestion of Dr. Cooper and Dr. Loeblich the writer undertook the investigation of the brachiopods and wishes to express his appreciation to both for their help and cooperation. In addition, Dr. Cooper made valuable suggestions and criticisms on the systematic paleontology and aided in preparing some of the fossils. Acknowledgments are due to the United States National Museum, which furnished the photographic equipment and supplies used in preparing the illustrations.

All the specimens used in this study are at the U. S. National Museum; the catalogue numbers of the types and figured specimens are indicated in the text and on the plate legends. Each of the individual collections has been given a separate number. The geographic location and stratigraphic position of each of these collections may be found in the table which accompanies this report.

The Henryhouse formation was originally described by C. A. Reeds in 1911 (pp. 261–262) as consisting of "bluish to yellowish, thin- to moderately thick-bedded earthy limestone and intercalated shale beds in the lower 180 feet, while the upper 43 feet is of white marly beds." Reeds did not describe or illustrate any of the fauna although he did give a list of fossils. This fauna was considered by him to be of Niaggaran age and he indicated that it was correlative with the "Bob" and "Lobelville" units of the Brownsport formation of western Tennessee.

In 1925 Gould published an "Index to the Stratigraphy of Oklahoma," and in this he repeated Reeds' lithologic description and faunal lists (p. 20).

C. E. Decker in 1935 described a fauna of graptolites from the Henryhouse formation. While collecting the material for this study, he measured the thickness of the formation at a number of places. The measurements made by him do not conform with those of Reeds. Decker found that the formation was usually less than 50 feet thick, with one of the greatest thicknesses being at the type locality, where the total Henryhouse formation was only 76 feet; at this same locality Reeds measured 180 feet.

In 1947 William Ham, A. R. Loeblich, Jr., and H. A. Lowenstam measured a number of sections and found that at the type locality the Henryhouse formation had a total thickness of 220.5 feet; one of the thickest sections measured by them was 251.4 feet at Chimney Hill Creek, 7 miles south of Ada (oral communication). Thus their measured sections would be more in accord with the thickness obtained by Reeds than with that of Decker.

Decker described 15 species of graptolites, of which 10 belong to the genus *Monograptus*. In his paper (1935, pp. 435–436), and in a later study published in 1936 (pp. 309–310), Decker noted that this graptolite assemblage was quite different from that found in most other North Ameri-

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can Silurian faunas, but was very much like that found in the lower Ludlow shales of Great Britain. He does, however, suggest that there are some similarities between the Henryhouse graptolite fauna and that of Cumings and Shrock's Mississinewa shale of northern Indiana. Decker states further that "because of the relation of the fauna of that shale (Mississinewa) to Silurian faunas of New York and Ontario, the Henryhouse would seem connected with the Silurian of those two regions."

A few specimens of the crustacean *Caryocaris* were found associated with the graptolite fauna. These were described by Ruedemann in 1935 (pp. 447–448), with three species being recognized.

In 1935 (p. 391) Ball and Maxwell published an abstract in which they stated that certain of the Henryhouse fossils listed by Reeds also occurred in the Bainbridge limestone of Missouri. A year later Maxwell published a short summary of his doctor's dissertation on "The Stratigraphy and Areal Distribution of the 'Hunton formation,' Oklahoma" (1936, pp. 131–136), but except for this neither Ball nor Maxwell appears to have written anything further on this subject.

In 1949 the writer published a paper on the stratigraphy and paleontology of the Brownsport formation of western Tennessee. During the course of this study the Reeds' Henryhouse collections at Yale University were examined and a tentative faunal list prepared; from this it was concluded that this formation was equivalent in age to the Brownsport (p. 34).

The present study of the Henryhouse brachiopods includes 27 genera and 41 species, of which 25 are new.

The close similarity of the Brownsport and Henryhouse brachiopod faunas is shown in the following table (*indicates that the species is present in the Brownsport but not described in the 1949 report).

TABLE 1.—COMPARISON OF BRACHIOPOD FAUNAS OF THE HENRYHOUSE AND BROWNSPORT FORMATIONS

HENRYHOUSE	BROWNSPORT
Parmorthis	Parmorthis
P. brownsportensis Amsden	P. brownsportensis Amsden
Rhipidomella	Rhipidomella
R. henryhousensis, n. sp.	R. cliftonensis (Amsden)
R. subtriangularis, n. sp.	R. lenticularis Foerste
R. acutisulcata, n. sp.	R. saffordi Foerste*
R. oklahomensis, n. sp.	
Isorthis	Isorthis
I. arcuaria (Hall & Clarke)	I. arcuaria (Hall & Clarke)
Dicaelosia	Dicaelosia
D. oklahomensis, n. sp.	D. oklahomensis (recorded 1949 as Bilobites cf. B. bilobus)
Schizoramma	Schizoramma
S. hami, n. sp.	S. fissiplica (Roemer)
Ptychopleurella	Ptychopleurella
P. rugiplicata (Hall & Whitfield)	P. rugiplicata (Hall & Whitfield)*
Orthostrophia	Orthostrophia
O. cf. O. brownsportensis Amsden	O. brownsportensis Amsden
	O. dixoni Foerste*
Dictyonella	Dictyonella
D. gibbosa (Hall)	D. gibbosa (Hall)
	D. concinna (Hall)
Not known	Rhipidium
	R. pinguis Amsden
	R. sewellensis Amsden
Sieberella	Sieberella
S. roemeri Hall & Clarke	S. roemeri Hall & Clarke
Anastrophia	Anastrophia
A. delicata, n. sp.	A. acutiplicata Amsden

TABLE 1—(*continued*)

HENRYHOUSE	BROWNSPORT
Strophonella	Strophonella
S. prolongata Foerste	S. prolongata Foerste
S. laxiplicata Foerste	S. laxiplicata Foerste
S. alterniradiata, n. sp.	S. dixoni Foerste
S. loeblichi, n. sp.	S. roemeri Foerste
Brachyprion	Not known
B. attenuata, n. sp.	
Leptaenisca	Not known
L. irregularis, n. sp.	
Lissostrophia (Amsden 1949)	Lissostrophia
L. cooperi, Amsden	L. glabella (Amsden)
Fardenia	Fardenia
F. reedsi, n. sp.	F. roemeri (Foerste)
F. attenuata, n. sp.	
F. sp.	
Leptaena	Leptaena
L. oklahomensis, n. sp.	L. tennesseensis Amsden
	L. delicata (?) Amsden
Camarotoechia	Camarotoechia
C. carmelensis Amsden, nom. nov.	C. carmelensis Amsden, nom. nov.
C. altisulcata, n. sp.	C. perryvillensis Amsden
C. oklahomensis, n. sp.	C. cedarensis Amsden
C. filistriata, n. sp.	C. shannonensis Amsden
	C. eccentrica Amsden
Not known	Trigonirhynchia
	T. tennesseensis (Roemer) emend. Amsden
Not known	Wilsonella
	W. saffordi (Hall)
	W. ? compressa Amsden
Atrypa	Atrypa
A. tennesseensis Amsden	A. tennesseensis Amsden
A. arctostriata Foerste	A. arctostriata Foerste
Not known	Plectatrypa
	P. brownsportensis Amsden
Lissatrypa	Lissatrypa
L. decaturensis Amsden	L. decaturensis Amsden
L. henryhousensis, n. sp.	
Nucleospira	Nucleospira
N. concentrica Hall	N. concentrica Hall*
Coelospira	Coelospira
C. saffordi (Foerste)	C. saffordi (Foerste)
Nanospira (Amsden 1949)	Not known
N. parvula, Amsden	
Delthyris	Delthyris
D. kozlowskii, n. sp.	D. saffordi (Hall)
Howellella	Not known
H. henryhousensis, n. sp.	
Merista	Merista
M. oklahomensis, n. sp.	M. tennesseensis Hall & Clarke
Meristina	Meristina
M. roemeri Foerste	M. roemeri Foerste
Homoeospira	Homoeospira
H. foerstei, n. sp.	H. elongata Foerste
H. subgibbosa, n. sp.	H. schucherti Foerste
	H. beecheri Foerste

The preceding list shows that the generic suites of these two formations are much alike. There are 27 genera recorded from the Brownsport and 27 from the Henryhouse, of which 23 are common to both.

Of the Brownsport genera only *Tri-*

gonirhynchia, *Wilsonella*, *Plectatrypa* and *Rhipidium* are absent from the Henryhouse. *Plectatrypa* is not especially abundant, but *Trigonirhynchia* and *Wilsonella* are common and widespread in the Brownsport, and their absence from the Henryhouse is rather puzzling. *Rhipidium* is found at only a few localities, but where present it usually occurs in large numbers. It is commonly found in relatively pure, massive limestone ledges and Dr. Loeblich has suggested (oral communication) that its absence from the Henryhouse may be associated with the absence of such limestone beds.

Of the 27 Henryhouse genera, *Brachyprion*, *Leptaenisca*, *Howellella* and *Nanospira* are the only ones not found in the Brownsport. *Leptaenisca* and *Howellella* are rather restricted in their development, but *Brachyprion* is fairly common and widespread. *Nanospira* is a new genus (Amsden 1949B, p. 203) with the only known species *N. parvula* (new species) being common in the Henryhouse.

Sixteen of the 41 described Henryhouse species are also present in the Brownsport, whereas the remaining 25 are new. Many of these new species show only slight, although distinct, specific variations from similar forms in the Brownsport.

This close similarity of the brachiopod faunas of these two formations clearly seems to indicate that they are closely related in age. The writer also believes that studies of the other elements of the Henryhouse will support this correlation. Other possible correlatives of these two formations have already been discussed by the author (1949A, pp. 32–36).

COLLECTION LOCALITIES

Collection

1. Henryhouse formation; about center of sec. 10, T. 2 N., R. 6 E., Pontotoc County, Okla.
2. Henryhouse formation, collection from a zone 44 to 94 feet above the base of the measured section (base of formation not exposed); center NE ¼ SW ¼ sec. 10, T. 2 N., R. 6 E., Pontotoc County, 8 miles south of Ada, Okla.
3. Henryhouse formation; east side of road in bluff for ½ mile; NW ¼, SW ¼, sec. 4, T. 2 N., R. 6 E., Pontotoc County, Okla.
4. Henryhouse formation, 125 feet above the contact of the Henryhouse and Chimneyhill; SW ¼, SE ¼, sec. 30, T. 2 S., R. 1 E.

EXPLANATION OF PLATE 15

FIGS. *1–7—Dicaelosia oklahomensis* Amsden, n. sp. *1*, *2*, *7*, brachial, lateral and pedicle views of the holotype (×5). Coll. 14. USNM 115251. *3*, *4*, brachial (×1) and posterior (×5) views of another specimen. Coll. 14. USNM 115252. *5*, pedicle interior (×5). Coll. 14, USNM 115253. *6*, brachial interior (×5). Coll. 14. USNM 115254. (p. 77)

8–13—Rhipidomella subtriangularis Amsden, n. sp. *8*, *11*, brachial (×1) and lateral (×2) views of the same specimen. Coll. 16. USNM 115256. *9*, *13*, pedicle and posterior views of the holotype (×2). Coll. 11. USNM 115255. *10*, brachial interior (×2). Coll. 16. USNM 115257. *12*, pedicle interior (×2). Coll. 18. USNM 115258. (p. 75)

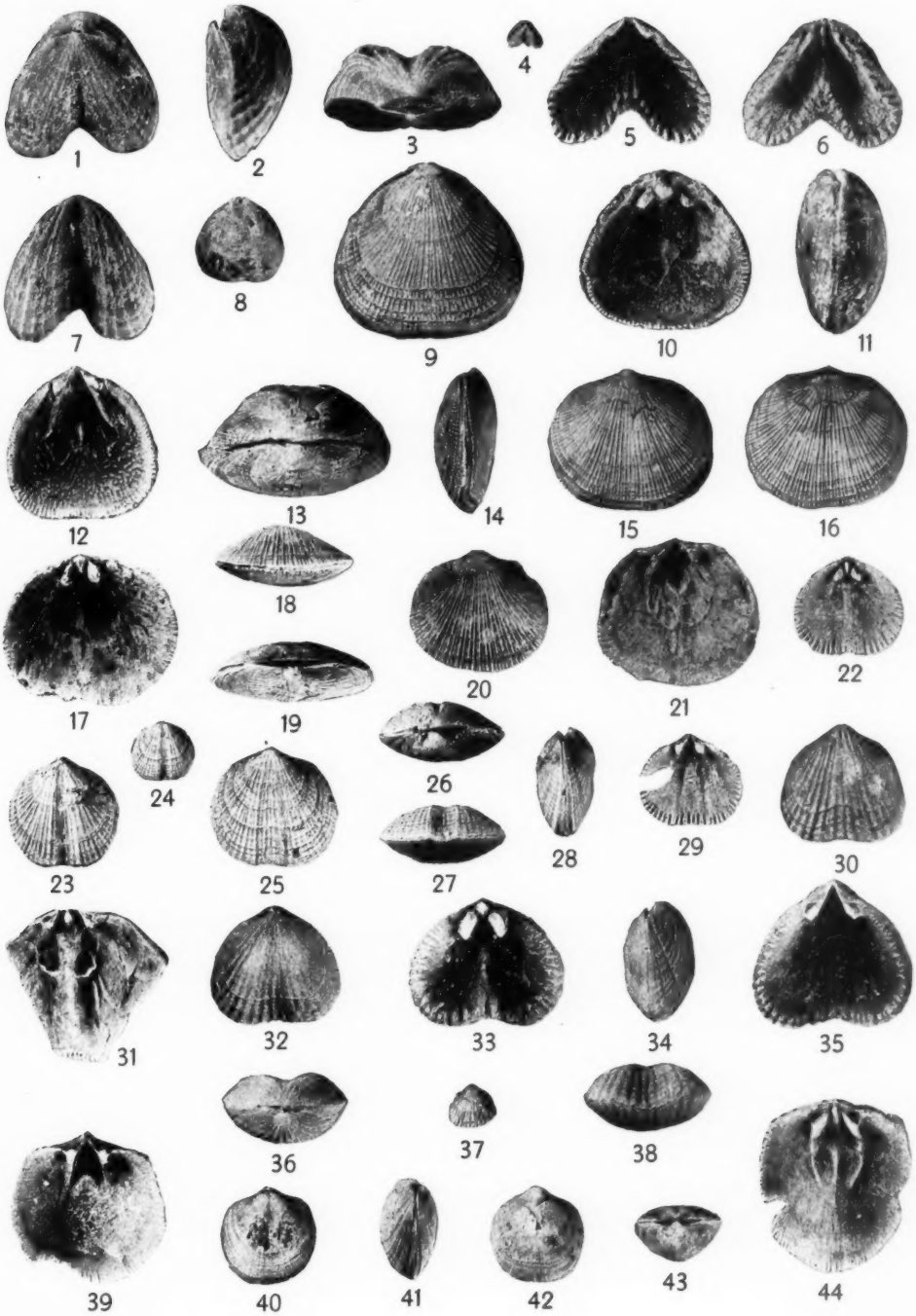
14–21—Rhipidomella henryhousensis Amsden, n. sp. *14–16*, *19*, lateral, pedicle, brachial and posterior views of the holotype (×1). Coll. 18. USNM 115259. *17*, interior view of a small brachial valve (×2). Coll. 13. USNM 115261. *18*, *20*, anterior and pedicle views of another specimen (×1). USNM 115262. *21*, pedicle interior (×1). USNM 115260. (p. 74)

22–29—Rhipidomella acutisulcata Amsden, n. sp. *22*, brachial interior (×2). USNM 115263. *23*, *28*, brachial and lateral views of the same specimen (×2). Coll. 12. USNM 115264. *24–27*, brachial (×1), pedicle, posterior and anterior (×2) views of the holotype. In the posterior and anterior views the pedicle valve is down. Coll 12. USNM 115265. *29*, pedicle interior (×2). Coll. 12. USNM 115266. (p. 75)

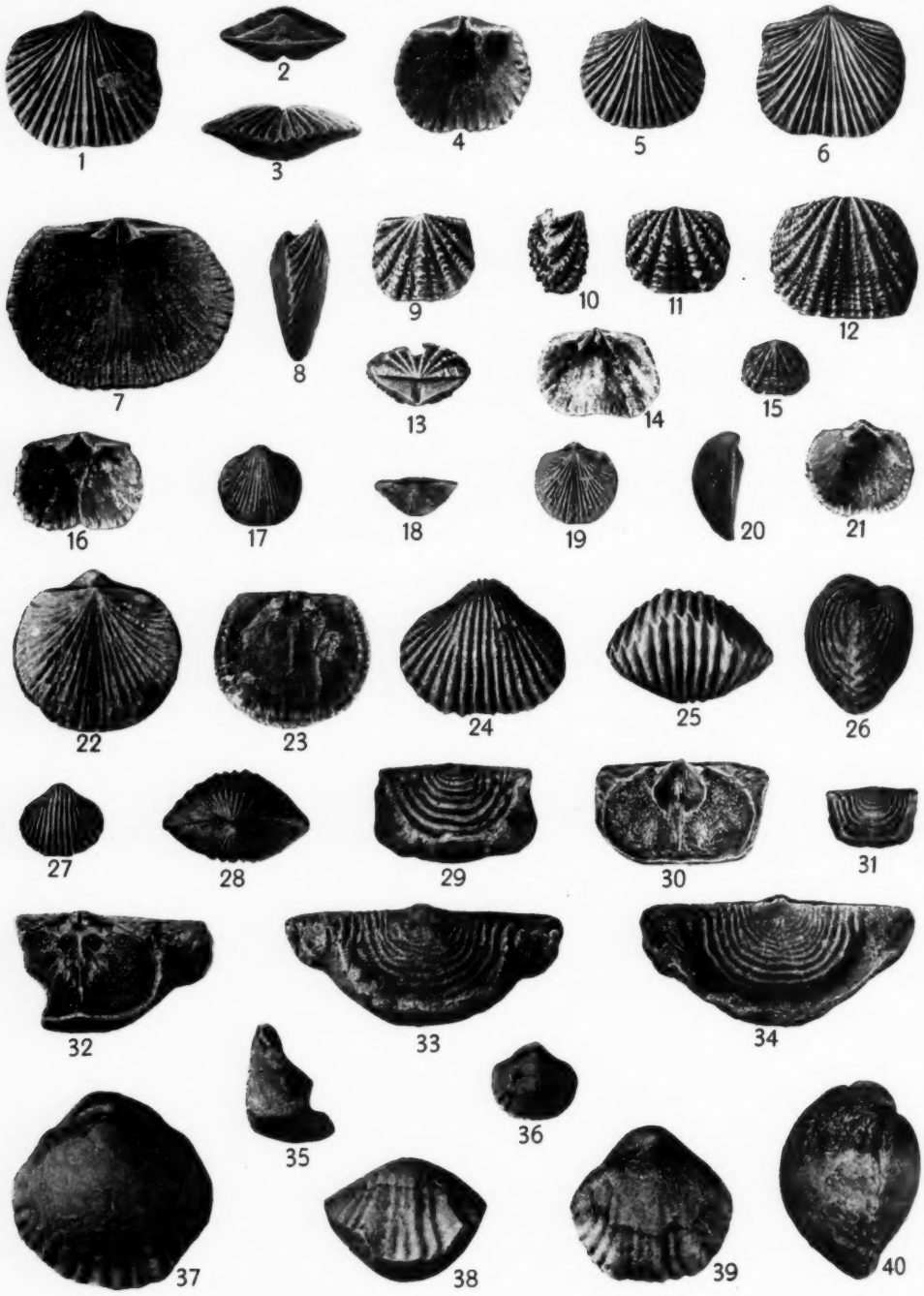
30, 32–38—Rhipidomella oklahomensis Amsden, n. sp. *30*, *32*, *34*, *36*, *38*, pedicle, brachial, lateral, posterior, and anterior views of the holotype (×3). Posterior and anterior views with the pedicle valve down. Coll. 3. USNM 115270. *33*, brachial interior of a small specimen (×5). Coll. 16. USNM 115268. *35*, pedicle interior (×5). Coll. 17. USNM 115269. *37*, pedicle view of another specimen (×1). Coll. 12. USNM 115267. (p. 76)

31—Orthostrophia cf. *O. brownsportensis* Amsden. *31*, brachial interior (×1). Coll. 3. USNM 115271. (p. 78)

39–44—Isorthis arcuaria (Hall and Clarke). *39*, pedicle, interior (×2). Coll. 2. USNM 115272. *40–42*, brachial, lateral and pedicle views of the same specimen (×1). Coll. 18. USNM 115274. *43*, posterior view of another specimen (×1). Coll. 12. USNM 115275. *44*, brachial interior (×2). Coll. 2. USNM 115273. (p. 76)



Amsden, Oklahoma Henryhouse formation brachiopods



Amsden, Oklahoma Henryhouse formation brachiopods

Carter County, 3 miles east of Woodford, Okla. This is the type locality of the Henryhouse formation.

5. Henryhouse formation; SE ¼, SE ¼, SW ¼, sec. 4, T. 2 N., R. 6 E., ½ mile SSW of Cedar Hill, Pontotoc County, Okla.
6. Henryhouse formation, 45 to 54 feet above the base of measured section (base of formation not exposed); SE ¼, NE ¼, NW ¼, sec. 30, T. 1 S., R. 2 E., Murray County, 4 miles south of Davis, Okla.
7. Henryhouse formation, 114 to 159.8 feet above the base of measured section (base of Henryhouse formation not exposed). Same geographic location as Collection 2.

No collection 8.

9. Henryhouse formation 94 to 114 feet above the base of the measured section (base of formation not exposed); same geographic location as Collection 2.
10. Henryhouse formation; NE ¼, NW ¼, NW ¼, sec. 10, T. 2 N., R. 6 E., Pontotoc County, Okla.
11. Henryhouse formation; NE ¼, SW ¼, SE ¼, sec. 4, T. 2 N., R. 6 E., Pontotoc County, Okla.
12. Henryhouse formation; SE ¼, SW ¼, SW ¼, sec. 3, T. 2 N., R. 6 E.; 1.8 miles W of Oklahoma Highway 99, 7–8 miles SSE of Ada, Okla.
13. Henryhouse formation; SE ¼, SE ¼, NE ¼, sec. 5, T. 2 N., R. 6 E., Pontotoc County, Okla.
14. Henryhouse formation, 40–60 feet above the base of the Henryhouse; Rock Crossing of Hickory Creek in Criner Hills, 7 miles SSW of Ardmore; 2,500 feet west, 2,000 feet north of SE cor. sec. 35, T. 5 S., R. 1 E., Carter County, Okla.
15. Henryhouse formation (upper); SW ¼, NW ¼, NW ¼, sec. 33, T. 3 N., R. 6 E., Pontotoc County, Okla.
16. Henryhouse formation (upper coral beds); N ½, SW ¼, sec. 4, T. 2 N., R. 6 E., Pontotoc County, Okla.
17. Henryhouse formation (lower); south side of road, SW ¼, SE ¼, SW ¼, sec. 2, T. 2 N., R. 6 E., Pontotoc County, Okla.
18. Henryhouse formation; Cedar Hill bluffs on north bank of South Fork of Jackfork Creek; S ½, sec. 4, T. 2 N., R. 6 E., Pontotoc County, Okla.
19. Henryhouse formation; SE ¼, SE ¼, SW ¼, sec. 4, T. 2 N., R. 6 E., Pontotoc County, Okla.
20. Henryhouse formation; SE ¼, SE ¼, SE ¼, sec. 4, T. 2 N., R. 6 E., Pontotoc County, Okla.
21. Henryhouse formation (lower); 400 feet east of center of sec. 29, T. 3 N., R. 6 E., Pontotoc County, Okla.
22. Henryhouse formation (upper); road cut, NE ¼, NE ¼, SE ¼, sec. 32, T. 3 N., R. 6 E., Pontotoc County, Okla.
23. Henryhouse formation, 80 to 120 feet above the contact of the Henryhouse and Chimneyhill; type locality; same geographic location as Collection 4.
24. Henryhouse formation, 30 feet above the pink crinoidal member of Chimneyhill limestone; NW¼, SE¼, NW¼, sec. 22, T. 1 N., R. 7 E., Pontotoc County, Okla.

Explanation of Plate 16

FIGS. *1–8—Schizoramma hami* Amsden n. sp. *1, 3, 6, 8*, pedicle, anterior, brachial and lateral views of the holotype (×1). Coll. 2. USNM 115276. *2, 5*, posterior and pedicle views of another specimen (×1). Coll. 2. USNM 115277. *4*, view of the interior of a small pedicle valve (×2). Coll. 13. USNM 115278. *7*, brachial interior (×2). USNM 115279. (p. 77)

9–16—Ptychopleurella rugiplicata (Hall and Whitfield). *9–11, 13*, pedicle, lateral, brachial and posterior views of an individual (×2). Coll. 1. USNM 115282. *12*, brachial view of another specimen (×2). Coll. 2. USNM 115283. *14*, brachial interior (×2). Coll. 13. USNM 115280. *15*, pedicle valve (×1). Coll. 21. USNM 115284. *16*, pedicle interior (×2). Coll. 13. USNM 115281. (p. 78)

17–23—Parmorthis brownsportensis Amsden. *17–19*, pedicle, posterior and brachial views of the same specimen (×1). Coll. 15. USNM 115285. *20*, lateral view of another specimen (×1). Coll. 3. USNM 115286. *21*, interior view of a small pedicle valve (×2). Coll. 16. USNM 115287. *22*, enlarged brachial (×2) view of the specimen shown in figs. *17–19*. Coll. 15. USNM 115285. *23*, brachial interior (×2). Coll. 16. USNM 115288. (p. 74)

24–28—Anastrophia delicata Amsden, n. sp. *24–26*, pedicle, anterior and lateral views of the holotype (×2). Coll. 1. USNM 115289. *27*, pedicle view of the holotype (×1). *28*, posterior view of another specimen (×2). Coll. 2. USNM 115290. In the anterior view of fig. *25* and the posterior view of fig. *28* the pedicle valve is down. (p. 79)

29–35—Leptaena oklahomensis Amsden, n. sp. *29*, pedicle view (×1). Coll. 16. USNM 115292. *30*, pedicle interior (×1). Coll. 10. USNM 115294. *31*, pedicle view (×1). This small individual has a well developed flange. Coll. 2. USNM 115291. *32*, brachial interior (×1). Coll. 10. USNM 115295. *33–35*, brachial, pedicle and lateral views of the holotype (×1). Coll. 13. USNM 115293. (p. 85)

36–40—Sieberella roemeri Hall and Clarke. *36*, brachial view of a small specimen (×1). Coll. 10. USNM 115296. *37, 40*, brachial and lateral views of a large individual (×1). Coll. 1. USNM 115297. *38, 39*, anterior and brachial views of a somewhat smaller individual (×1). Coll. 13. USNM 115298. (p. 79)

25. Henryhouse formation, 35 to 80 feet above the contact of the Henryhouse and Chimneyhill; same geographic location as Collection 4.
26. Henryhouse formation (marly beds); NW ¼, SW ¼, NW ¼, sec. 33, T. 3 N., R. 6 E., Pontotoc County, Okla.
27. Henryhouse formation, 100 to 110 feet below the contact of the Henryhouse and Bois d'Arc; Chimneyhill Creek and bluff to north, center E ½, SE ¼, sec. 5, and NW ¼, SW ¼, sec. 4, T. 2 N., R. 6 E., 7 miles south of Ada, Pontotoc County, Okla.
28. Henryhouse formation (upper marly beds); NE ¼, NW ¼, NW ¼, sec. 10, T. 2 N., R. 6 E., Pontotoc County, Okla.
29. Henryhouse formation, 190 feet below the Bois d'Arc limestone; same geographic location as collection 27.

Phylum BRACHIOPODA
Class ARTICULATA
Superfamily DALMANELLACEA
Genus PARMORTHIS Schuchert and Cooper 1931
PARMORTHIS BROWNSPORTENSIS
Amsden
Plate 16, figures 17–23

P. brownsportensis AMSDEN 1949A (pp. 42–43, pl. 1, figs. 1–6).

Discussion.—The specimens of this species from the Henryhouse formation are similar to those from the Brownsport formation. An individual of average size measures 14 mm. long by 13 mm. wide and 6 mm. deep; the largest in the collection is 18 mm. long. Most of the specimens have about 14 costellae in a distance of 5 mm., although one or two have as many as 18 in this distance. A number of interiors of both valves in the collections show the typical internal characters of the genus *Parmorthis* (Schuchert and Cooper 1931, p. 246; 1932, p. 128, pl. 21, figs. 1–16, 29).

Distribution.—This is a common species in the Henryhouse formation; the following collections are represented: 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, 22, 27, 28?, 29. It is also abundant in the Brownsport formation of western Tennessee, where it was originally referred to *Orthis elegantula* (Roemer 1860, p. 62, pl. 5, fig. 7; Foerste 1903, p. 711), later being placed in the genus *Parmorthis* and made the type for a new species (Amsden 1949A). Reeds makes no mention of this species in his paper on the Henryhouse formation (1911).

Genus RHIPIDOMELLA
Oehlert 1890
RHIPIDOMELLA HENRYHOUSENSIS
Amsden, n. sp.
Plate 15, figures 14–21

Description.—The shell of this species is subelliptical in outline, with the width greater than the length. The lateral profile is biconvex; in immature shells the pedicle valve usually has the greater convexity, but as they approach maturity the two valves become about equal, or in some cases the brachial may develop the greater convexity. In young shells the hinge line is equal to about one-half the length of the valve, but in older specimens it becomes relatively shorter, approaching one-third the length of the valve. The interareas are small, orthocline, and about equal to one another. The pedicle beak is small and not strongly incurved over the brachial; at the posterior end the pedicle valve is strongly convex with the umbo sharply defined, but toward the anterior end it becomes flattened and in some specimens develops a broad and poorly defined sulcus. A shallow, brachial sulcus begins just anterior to the beak; this extends for one-third to one-half the length of the valve and then disappears, in some specimens being replaced by a very faint fold. The surface of the valves is multicostellate with 12 to 14 costellae in a distance of 5 mm. Mature specimens average about 23 mm. wide, 20 mm. long, and 9 mm. deep.

The pedicle interior has semiflabellate, fairly deeply impressed muscle scars, as shown in plate 15, figure 21; the brachial interior is shown in figure 17 of plate 15.

Discussion.—Externally this species is rather similar to *R. lenticularis* (Foerste 1903, p. 711; 1909, p. 72, pl. 2, figs. 28A, B; *Mendacella? lenticularis*, Amsden 1949A, pp. 43–44, pl. 1, figs. 20–21), but differs in that the hinge line is longer and the costellae less sharply defined. The internal characters of *R.? lenticularis* have not been described.

R. henryhousensis is a larger species, with slightly coarser ribbing, than *R. cliftonensis* from the Brownsport (Amsden 1949A, p. 43). In 1949 the writer referred the species

cliftonensis to the genus *Mendacella*, primarily upon the basis of what were interpreted as fulcral plates (1949A, pl. 15, fig. 10). Aside from these fulcral plates the internal characteristics of this species are much more like those of typical *Rhipidomella* than of *Mendacella*, and it now seems advisable to make this change in the generic name. Such plates have not been observed in *R. henryhousensis*, but otherwise the interiors of these two species are very similar.

In this report four species have been referred to the genus *Rhipidomella; R. henryhousensis, R. subtriangularis, R. acutisulcata,* and *R. oklahomensis.* All of these species have similar brachial interiors (compare figs. 10, 17, 22, and 33 of pl. 15), but the pedicle interiors show much more variation. The pedicle valves of *R. henryhousensis* and *R. subtriangularis* show the rather deeply impressed, semiflabellate muscle scars that are characteristic of this genus. On the other hand *R. acutisulcata* and *R. oklahomensis* show a somewhat different pedicle interior. In *R. oklahomensis* the pedicle musculature is faint and poorly defined, while in *R. acutisulcata* the diductor scars are elongate and subparallel. For the present it seems best to refer all these species to *Rhipidomella*, but further study of the Silurian dalmanellids may show that one or two new genera are needed.

The individuals of *R. henryhousensis* show considerable variation. This is especially true in regard to the convexity of the two valves and the degree of flattening in the anterior portion of the pedicle valve.

This may be the species which Reeds (1911, p. 267) called *R. oblata.*

Holotype.—USNM No. 115259.

Distribution.—Specimens of this species are abundant in the Henryhouse formation; the following collections are represented: 1, 2, 3, 4, 5, 7, 10, 11, 12, 13, 15, 16, 17, 18, 19, 21, 22, 26, 27, 28, 29. Type locality, 18.

Rhipidomella subtriangularis
Amsden, n. sp.
Plate 15, figures 8–13

Description.—The shell of this species is subtriangular in outline, with the greatest width near the anterior end. The hinge line is short, a shell 13 mm. long having a hinge line 3 mm. long. It is biconvex, with the brachial valve having the greater convexity. The pedicle beak is rather small and erect; at the posterior end the pedicle valve is moderately convex, but it begins to flatten at about midlength and is only gently convex at the anterior margin. The brachial valve is strongly convex; the anterior half of some valves tends to develop a flattening along the midline that may even develop into a shallow, poorly defined sulcus. This species has a shell that is thick for its size; it is multicostellate, with approximately 15 costellae in a distance of 5 mm. A mature specimen measures 13 mm. long, 14 mm. wide, and 8 mm. thick.

The pedicle interior has deeply impressed, semiflabellate diductor muscle scars that extend over half the length of the valve (plate 15, fig. 12). The brachial interior is shown on plate 15, figure 10. (See also under discussion, *R. henryhousensis.*)

Discussion.—Mature specimens of this species are much smaller than are adult specimens of *R. henryhousensis.* Shells of the latter that are comparable in size differ in their more circular outline, less convex dorsal valve, and thinner shells. Also the muscle scars of *R. subtriangularis* are larger and more deeply impressed. This may be the species which Reeds (1911, table II, p. 267) called *R. emarginata.*

Holotype.—USNM No. 115255.

Distribution.—This is not a common species in the Henryhouse formation; there are about 30 specimens from the following collections: 1, 3, 5, 11, 12, 13, 16, 18. Type locality, 11.

Rhipidomella acutisulcata
Amsden, n. sp.
Plate 15, figures 22–29

Description.—This small species has a shell subcircular in outline with the width slightly greater than the length; the anterior margin is fairly straight. It is biconvex, with the two valves about equal in convexity, although some specimens have a pedicle valve which is slightly larger than the brachial. The pedicle beak is small and erect. A fold is present on the pedicle valve; this begins just anterior to the beak and remains low throughout its length; this fold bears five or six costellae and is marked off from the rest of the valve by two small but

distinct furrows. The brachial valve bears a sulcus that begins about 1 mm. in front of the beak and extends to the anterior margin. This sulcus, although narrow and never very deep, is sharply marked off from the rest of the valve by relatively steep sides; there are about six costellae on the sulcus, but these are not as strongly developed as those on the lateral margins. The surface of the valve bears low, rounded costellae, of which about 12 occupy a distance of 5 mm. A mature specimen of average size measures 8 mm. long, 9 mm. wide and 4 mm. thick.

The pedicle diductor muscle scars are moderately long and narrow, as shown in plate 15, figure 29. In the brachial valve the internal structures are quite similar to those of the other Rhipidomellas from the Henryhouse (plate 15, fig. 22). (See also under discussion, *R. henryhousensis*.)

Discussion.—This species is similar to the Brownsport species, *R. saffordi* (Foerste 1903, p. 711, 1909, p. 72, pl. 1, figs. 17A–C), but a direct comparison with Foerste's types shows that *R. acutisulcata* has a narrower and more sharply defined brachial sulcus. Furthermore, the Brownsport species appears to lack the ventral fold.

This may be the species that Reeds (1911, p. 263) called *Bilobites saffordi* and listed as occurring in the Henryhouse formation. Some uncertainty exists, because this is the only reference to a *Bilobites saffordi* which has been found.

Holotype.—USNM No. 115265.

Distribution.—This species is only moderately abundant in the Henryhouse formation; there are about 50 specimens from collections: 3, 11, 12, 13?, 15, 16, 18, 22, 26. Type locality, 12.

Rhipidomella oklahomensis Amsden, n. sp.
Plate 15, figures 30, 32–38

Description.—This species is subtriangular in outline, with the anterior margin indented along the midline to give a slightly bilobed appearance. It is biconvex in lateral profile, with the pedicle valve having a slightly greater convexity. The pedicle valve has a small, erect beak and a low, poorly defined fold that begins about one-third of the distance from beak to border and extends to the anterior margin. The brachial valve has a rather broad and deep sulcus which at the anterior end of a mature specimen bears seven to nine costellae. The surface of the valves is covered with rounded costellae, eight or nine occupying a distance of 3 mm. Mature specimens are about 6 mm. wide, 5.5 mm. long, and 3 mm. thick; one of the largest in the collection is 7 mm. wide, 6.5 mm. long, and 3.5 mm. thick. Considering its small size this species has a very thick-walled shell.

The pedicle muscle scars are shallow and faint; the diductors are elongate, subparallel to one another (plate 15, fig. 35). Figure 33 of plate 15 shows the brachial interior. (See also under discussion, *R. henryhousensis*.)

Discussion.—Mature specimens of *R. oklahomensis* are smaller than mature specimens of *R. acutisulcata*. When it is compared with immature specimens of *R. acutisulcata* of the same size, it may be seen to differ in its shorter hinge line, more triangular outline and thicker-walled shell. In addition, the brachial sulcus of *R. oklahomensis* is broader and less sharply defined than is that of *R. acutisulcata*.

Holotype.—USNM No. 115270.

Distribution.—This species is present in collections: 2, 3, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 26, 27, 28, 29. It is abundant in 2, 8, 10, 13, 17. Type locality, 3.

Genus Isorthis Kozlowski 1929
Isorthis arcuaria (Hall and Clarke)
Plate 15, figures 39–44

Orthis (Dalmanella) arcuaria Hall and Clarke 1892 (pp. 224, 341, pl. 5c, figs. 20, 21).
Isorthis arcuaria Amsden 1949A (p. 44, pl. 1, figs. 12–16).

Discussion.—This species has a multicostellate shell bearing 18 to 20 costellae in a distance of 5 mm. Individuals from the Henryhouse formation are slightly larger than those from the Brownsport formation, a specimen of average size being 14 mm. long, 14 mm. wide, and 8 mm. deep; the largest individual in the collection has a length of about 17 mm.

The shell is rather thin, and consequently many of the specimens show some distortion.

Distribution.—This is a common species

in the Henryhouse formation, with specimens from the following collections: 1, 2, 3, 5, 10, 11, 12, 13, 14, 16, 17, 18, 19, 21, 22, 27, 28, 29. It is also well represented in the Brownsport formation.

Genus DICAELOSIA King 1850
(*Bilobites* of authors; see Cloud 1948, pp. 373–374)
DICAELOSIA OKLAHOMENSIS
Amsden, n. sp.
Plate 15, figures 1–7

Description.—This species has a small shell that is strongly bilobed in front. The hinge line is short, being less than half the greatest width of the shell. Its lateral profile is biconvex, with the pedicle valve about twice as deep as the brachial. The pedicle interarea is larger than the brachial, and apsacline. The pedicle beak does not curve over the brachial valve; there is a pedicle sulcus which begins just in front of the beak and extends as a deep depression to the anterior margin. There is a corresponding brachial sulcus, although it is not as deep as the pedicle sulcus; the junction of these two depressions produces the strongly bilobed shell. The surface is covered with low, rounded costellae that become obsolete in the sulcus of the brachial and pedicle valves. There are 11 to 13 costellae on each lateral lobe of each valve; these are crossed by growth lines, which are almost equal in size to the costellae. Mature specimens measure about 4.5 mm. long, 5 mm. wide, and 2.5 mm. thick.

The pedicle interior has stout teeth and muscle scars that are shallow and not well-defined (pl. 15, fig. 5). A small cardinal process occurs in the brachial valve, and blade-like brachiophores, as shown in plate 15, figure 6. The shell wall is relatively thick and coarsely punctate.

Discussion.—These specimens from the Henryhouse formation appear to be similar to those from the Brownsport. Specimens from both formations differ from *D. biloba* (Linnaeus 1767, p. 1154), from Gotland, in that the latter has a median sulcus in both valves which is deeper and more broadly rounded.

Holotype.—USNM No. 115251.

Distribution.—This species is abundant in the Henryhouse, with specimens from the following collections: 1, 2, 3, 5, 9, 10, 11, 13, 14, 15, 16, 17, 19, 22, 26, 28, 29. Type locality, 14.

Superfamily ORTHACEA
Genus SCHIZORAMMA Foerste 1912
SCHIZORAMMA HAMI Amsden, n. sp.
Plate 16, figures 1–8

Description.—*S. hami* is subcircular in outline, wider than long, with the hinge line less than the greatest width of the shell. In lateral profile it is biconvex, with the pedicle valve having the greater convexity. The pedicle palintrope is large, slightly curved and strongly apsacline. The pedicle beak is sharp and erect; this valve is convex with the curvature sloping uniformly away from the beak. A sulcus on the brachial valve begins about one millimeter in front of the beak; this is deep and narrow on the posterior half of the valve but becomes broad and less well defined at the anterior end. The surface is covered with costellae that are high and narrow at the posterior end, but these increase in size as they progress forward, so a mature specimen measuring 18 mm. in length has about eight costellae in a distance of 10 mm. The interspaces are broad and angular and crossed by concentric filae that become obsolete on the summits of the costellae. A mature specimen of average size measures 23 mm. wide, 18 mm. long, and 8 mm. thick; the largest specimen in the collections is 30 mm. wide by 23 mm. long.

The pedicle interior has receding dental plates that have their base extended forward as a low ridge encircling the muscle field (pl. 16, fig. 4). The brachial interior has a thin, linear cardinal process, as shown in plate 16, figure 7.

Discussion.—This species is larger than *S. fissiplica* (Roemer 1860, p. 64, pl. 5, figs. 5a, b; Amsden 1949A, p. 45, pl. 1, figs. 22–25) and has thicker costellae. The pedicle valve of *S. hami* is much more convex and higher than *S. fissiplica*, so that on specimens of comparable size the pedicle palintrope of the Henryhouse species is almost twice as wide as that of the Brownsport species.

Reeds (1911, p. 63) identified this species as *Hebertella fissiplica*.

This species is named for William Ham of the Oklahoma Geological Survey.

Holotype.—USNM No. 115276.

Distribution.—This is a moderately common species in the Henryhouse formation and is present in collections: 1, 2, 5?, 7, 9, 10, 13, 15, 16, 18, 20, 22, 26, 28. Type locality, 2.

Genus PTYCHOPLEURELLA Schuchert and Cooper 1931
PTYCHOPLEURELLA RUGIPLICATA (Hall and Whitfield)
Plate 16, figures 9–16

Orthis rugiplicata HALL and WHITFIELD 1872 (p. 182).

Description.—The lateral profile of this small species is biconvex, with the pedicle valve being subpyramidal. Its outline is subelliptical with the greatest width at about midlength. The palintrope of the pedicle valve is broad, strongly apsacline and cleft by a long slit-like delthyrium. The sulcus on the brachial valve originates just in front of the beaks and becomes broad but not deep towards the anterior margin; the pedicle valve is uniformly convex without any distinct fold. The surface of both valves is ornamented by prominent, rounded costae; a mature specimen measuring about 9 mm. in length will bear about 25 costae on each valve. These costae are crossed by conspicuous, imbricating lamellae that are best developed on the crests of the costae along the anterior half of the valves. Well preserved specimens show that as these lamellae cross the crests they commonly extend forward as small, spine-like processes (pl. 16, figs. 9–11).

The brachial and pedicle interiors are shown on figures 14, 16 of plate 16.

Discussion.—Hall and Whitfield's description of this species was based upon specimens from the Louisville limestone. The writer has examined specimens from this formation and finds them to be similar in shape and ornamentation to those from the Henryhouse, although the Louisville shells do appear to be slightly smaller. This species also occurs in the Brownsport formation and here also the specimens seem to be somewhat smaller than in the Henryhouse.

The delthyrium of *P. rugiplicata* shows the "side plates" described by Twenhofel (1914, p. 25).

Distribution.—*P. rugiplicata* is present in the Louisville, Brownsport, and Henryhouse formations. It is a common species in the Henryhouse and is represented in collections: 1, 2, 3, 5, 7, 10, 13, 15, 16, 17, 19, 20, 21, 22, 26, 27, 28, 29.

Genus ORTHOSTROPHIA Hall 1883
ORTHOSTROPHIA cf. O. BROWNSPORTENSIS Amsden
Plate 15, figure 31

Orthostrophia brownsportensis AMSDEN 1949A (pp. 45–46, pl. 1, fig. 26, pl. 34, figs. 1, 4).

Discussion.—The collections under study include only three fragmentary specimens belonging to the genus *Orthostrophia.* These are too incomplete to make more than a tentative specific identification, but they do appear to be similar to *O. brownsportensis.*

Distribution.—The three specimens in the collections came from collections 3 and 18.

TAXONOMIC POSITION UNCERTAIN
Genus DICTYONELLA Hall 1867
DICTYONELLA GIBBOSA (Hall)
Plate 20, figures 7–12

Eichwaldia gibbosa HALL 1867 (p. 268; Hall and Clarke 1894, pl. 83, figs. 6, 7).
Dictyonella gibbosa AMSDEN 1949A (p. 62, pl. 8, figs. 1–8).

Discussion.—Specimens of this species from the Henryhouse formation are very similar to those from the Brownsport, although the latter perhaps do not reach quite as large a size. The pedicle sulcus usually appears 5 or 6 mm. in front of the beak, although some specimens show a flattening along the midline up to the beak. This sulcus never becomes very deep but is usually well defined in the anterior half of the valve. On the brachial valve the fold appears 6 or 7 mm. in front of the beak and becomes fairly well defined in the anterior portion of the shell. Mature specimens reach the dimensions of 16 mm. long, 18 mm. wide, and 9 mm. thick.

Distribution.—Brownsport formation of western Tennessee; Henryhouse formation of Oklahoma. There are about 40 specimens from collections 1, 2, 3, 5, 13, 14, 16, 19, 22, 26, 28, 29.

Superfamily PENTAMERACEA
Genus SIEBERELLA Oehlert 1887
SIEBERELLA ROEMERI Hall and Clarke
Plate 16, figures 36–40

Sieberella roemeri HALL and CLARKE 1892 (p. 247, pl. 2, fig. 6).
Sieberella roemeri AMSDEN 1949A (pp. 49–50, pl. 2, figs. 1–4).

Discussion.—There is much variation among the specimens of this species from the Henryhouse formation, especially in the coarseness of the plications and the development of the brachial sulcus and pedicle fold. In some specimens the fold and sulcus is obscure (pl. 16, fig. 36), but in others it is well-developed (pl. 16, figs. 38, 39), as in the typical Brownsport forms. In addition to the broad, rounded plications the valves are marked with very fine, concentric filae. Mature specimens from the Henryhouse are as large as 28 mm. long, 29 mm. wide, and 20 mm. thick.

Etched specimens show this species has the internal characters which are typical of the genus *Sieberella* (Schuchert and Cooper 1932, p. 175).

There are many specimens of this species in the collections, but the larger individuals are usually poorly preserved.

This species was called *Gypidula roemeri* by Reeds (1911, p. 263).

Distribution.—Brownsport formation of western Tennessee; Henryhouse formation of Oklahoma. It is abundantly represented in the present collections with specimens from the following: 1, 2, 3, 4, 5, 7, 9, 10, 12, 13, 16, 17, 18, 19, 20, 22, 24, 26, 27, 28.

Superfamily SYNTROPHIACEA
Genus ANASTROPHIA Hall 1867
ANASTROPHIA DELICATA Amsden, n. sp.
Plate 16, figures 24–28

Description.—This small species is biconvex, with the brachial valve having the greater convexity. The beaks of both valves are incurved, with that of the pedicle valve curving over the brachial. The pedicle sulcus, which appears at about midlength, extends to the front of the shell as a shallow, poorly defined depression; this sulcus bears four to six plications. The brachial valve is gibbous, with a low fold beginning at about the middle of the shell and extending to the anterior margin as a somewhat poorly defined elevation; this bears five to seven plications. The surface is covered with angular plications crossed by faint, concentric growth lines which, although never prominent, are best developed on the sides of the plications. A mature specimen of average size measures about 10 mm. long, 12 mm. wide, and 7 mm. thick.

Several well preserved interiors of both valves show that this species has the typical internal structures of the genus *Anastrophia* (Schuchert and Cooper 1932, p. 169).

Discussion.—This is the species which Reeds identified as *A.* cf. *A. internascens* (1911, p. 263), but the Waldron species is much larger and has more prominent plications than *A. delicata*. The Brownsport species *A. acutiplicata* (Amsden 1949A, pp. 50–51, pl. 2, figs. 5–9) is larger and has a more prominent fold and sulcus than *A. delicata*.

Holotype.—USNM No. 115289.

Distribution.—This species is only moderately common in the Henryhouse formation; the following collections represented: 1, 2, 3, 5, 9, 10, 11, 13, 15, 16, 17, 18, 19, 22, 26, 27, 29. Type locality, 1.

Superfamily STROPHOMENACEA
Genus STROPHONELLA Hall 1879
STROPHONELLA PROLONGATA Foerste
Plate 18, figures 52–57

Strophonella prolongata FOERSTE 1903 (p. 710; 1909, p. 85, pl. 2, figs. 23A, B).
Strophonella prolongata AMSDEN 1949A (p. 51, pl. 5, figs. 8–10.

Discussion.—Specimens of this species from the Henryhouse are very similar in size, shape, and ornamentation to those from the Brownsport formation. The costellae are sharp and separated by rounded interspaces; they are uniform in size and not fasciculate. A mature specimen of average size will measure about 23 mm. wide along the hinge, 7 or 8 mm. from the beak to the point of geniculation, and 10 mm. or so from here to the anterior margin.

Neither Foerste nor Amsden illustrated any interiors of this species, but the Henryhouse collections include several well preserved specimens; a brachial and a pedicle are illustrated on figures 56 and 57 of plate 18.

In this report the writer has referred the

following species to the genus *Strophonella: S. prolongata, S. alterniradiata, S. laxiplicata,* and *S. loeblichi.* The pedicle interiors of these species have a number of features in common (pl. 18, figs. 46, 56; pl. 20, figs. 5, 38); the diductor muscle scars are rather deeply impressed, semiflabellate and separated from one another by a median septum. This median septum is well-developed in *S. prolongata, S. alterniradiata,* and *S. loeblichi,* but is rather weak in *S. laxiplicata.* The hinge line of all four species is partially denticulate, these denticulations extending for a distance ranging from one-third to one-half the length.

The brachial interiors show more variation; *S. laxiplicata* and *S. loeblichi* (figs. 1, 36, of plate 20) are somewhat similar to one another, but that of *S. prolongata* (fig. 57, pl. 18) is quite different, having much more massive cardinalia, with a prominent median septum at the posterior end that becomes reduced in the central part of the valve, where it is flanked by two septa. The brachial interior of *S. alterniradiata* has not been observed.

These differences strongly suggest that species with the internal characters of *S. prolongata* (possibly including *S. alterniradiata*) should be generically separated from *S. loeblichi* and *S. laxiplicata;* furthermore, it is possible that these last two species could be generically distinguished fron one another.

Caster (1939, p. 103) has recommended that the genus *Strophonella* be restricted to those species with the alternating type of costellae. If this characteristic is used, then it seems strongly probable to the author that more than one genus will need to be recognized within the alternating group. The Henryhouse species show that the internal characters of *S. laxiplicata,* with non-alternating costellae, are more like those of *S. loeblichi,* with the alternating type, than they are like those of the evenly ribbed *S. prolongata.* Although there are no brachial interiors of *S. alterniradiata* in the collections it seems probable on the basis of similarities of the exteriors and of the pedicle interiors that this species is congeneric with *S. prolongata.*

It seems best to the writer to assign all these species to the genus *Strophonella* until such time as the Silurian Strophomenacea can be studied as a group.

Distribution.—This species is much more common in the Henryhouse than it is in the Brownsport formation. Specimens from collections, 1, 2, 3, 5, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 21, 22, 29.

STROPHONELLA ALTERNIRADIATA
Amsden, n. sp.
Plate 18, figures 45–51

Description.—This species has a profile which is geniculate and resupinate. The brachial valve is rather flat or even concave for a distance of about 8 mm. in front of the beak; it is then abruptly deflected toward the pedicle so that the anterior portion of the valve is almost at right angles to the posterior portion. The area just in front of the pedicle beak is slightly convex but this is soon lost and the curvature is sharply reversed, with the pedicle valve closely paralleling the brachial to produce a shallow living chamber. The greatest width of the shell is along the hinge line, where the lateral margins are produced into points. The surface of both valves is covered with rounded costellae of the alternating type; on the anterior deflected portion the costellae are of two distinct sizes with the more prominent set separated from one another by three to six much smaller costellae. Along the anterior margin six to eight of the large size occupy a distance of 5 mm. As the costellae are traced posteriorly the size distinction becomes less conspicuous and in the area around the beaks it is difficult to distinguish two ranks. A specimen of average size will measure about 20 mm. long at the hinge line, 10 mm. from the beak to the deflected portion, and about 10 mm. from here to the anterior margin.

The pedicle interior of this species is very similar to that of *S. prolongata,* although the muscle scars do not appear to be quite as deeply impressed (pl. 18, fig. 46). Both species are denticulate for about half the length of the hinge line. No brachial interiors have been seen, but presumably this valve is also much like that of *S. prolongata.* (See discussion of *S. prolongata.*)

Discussion.—*S. alterniradiata* is very much like *S. prolongata* in its size, outline, and profile. The two differ in that *S. alterni-*

radiata has much finer, more closely spaced costellae of the alternating type; *S. prolongata*, on the other hand, has relatively coarse costellae, all of which are more or less equal in size. As the costellae of *S. prolongata* become much finer as they approach the beaks, and as the alternating character of the costellae of *S. alterniradiata* becomes much less distinct toward the beaks, some difficulty is experienced in distinguishing immature specimens of the two species.

Holotype.—USNM No. 115340.

Distribution.—This is not a common species in the Henryhouse formation; specimens from collections 2, 3, 7, 13, 15, 16, 22. Type locality, 7.

STROPHONELLA LAXIPLICATA
Foerste
Plate 20, figures 1–6

Strophonella laxiplicata FOERSTE 1903 (p. 711; 1909, p. 86, pl. 2, figs. 25A, B).

Discussion.—This species has a large, resupinate shell. The posterior portion of the pedicle valve is slightly convex, with the reversal of curvature taking place 10 to 12 mm. in front of the beaks. The brachial valve is slightly concave at the posterior end and then reverses its curvature, rather closely paralleling the ventral valves. Foerste's description of the ornamentation applies very well to the Henryhouse specimens and is as follows: "The striae [costellae] are rather sharply elevated above the general surface of the shell; and are separated by comparatively wide spaces in which intermediate striae [costellae] are absent or practically obsolete. Only a small number of striae [costellae], usually less than 10, begin at the beak, and new plications are added, usually by intercalation, appearing near the middle of the comparatively wide intermediate spaces." Foerste also noted that the interspaces are crossed by concentric striae [filae]; these are very faint and can only be seen with the aid of a lens. One of the largest specimens of this species in the Henryhouse collections measures about 40 mm. wide and 30 mm. long.

The palintrope of the pedicle valve is about twice as wide as that of the brachial, and the hinge line is denticulate for approximately one-half its length. The brachial and pedicle interiors are shown on figures 1 and 5 of plate 20. (See discussion under *S. prolongata*.)

Distribution.—This species is somewhat more abundant in the Henryhouse than in the Brownsport formation. The Henryhouse collections include about 30 specimens from the following: 1, 2, 3, 5, 7, 10, 11, 12, 13, 16, 18, 22.

STROPHONELLA LOEBLICHI
Amsden, n. sp.
Plate 20, figures 36–41.

Description.—This species has a large, resupinate shell. It is subcircular in outline, with the hinge line forming the greatest width of the shell. The posterior portion of the pedicle valve is gently convex, but this is soon reversed, the point of reversal of curvature taking place between 10 and 15 mm. in front of the beak; in mature shells the pedicle valve is strongly concave although not geniculate. The brachial valve is flat for a distance of 10 to 15 mm. anterior to the beak, and then it becomes convex, closely following the pedicle valve. The palintrope of both valves is well developed, that of the pedicle being about twice as wide as the brachial. The surface is covered with low, rounded costellae of the alternating type, with the more prominent costellae separated from one another by seven to ten much finer ones; about four of the large costellae occupy a distance of 5 mm. The largest specimen in the collection measures 45 mm. wide, 37 mm. long, and 12 mm. thick.

The pedicle interior of this species (pl. 20, fig. 38) is similar to that of *S. prolongata* and *S. alterniradiata*, but the denticulations do not occupy as great a portion of the hinge line; in these two species the denticulations extend for about one-half the length of the hinge line, whereas in *S. loeblichi* they extend for only a third. In spite of the fact that *S. loeblichi* is a much larger shell the cardinalia are not nearly as massive as in *S. prolongata;* furthermore, the dorsal median septum of *S. loeblichi* is only very weakly developed (compare fig. 36 of plate 20, to fig. 57 of plate 18). (See discussion under *S. prolongata*).

Discussion.—Immature specimens of this species are similar to *S. tenuistriata* (Foerste 1909, p. 83, pl. 2, figs. 20A, B), but the larger

costellae of *S. loeblichi* are more widely spaced and have a larger number of the smaller costellae between them. Mature specimens are more like *S. roemeri* (Foerste 1909, p. 84, pl. 2, fig. 24), but they are not subtrigonal in outline and the prominent costellae are more widely spaced.

This species named for Dr. A. R. Loeblich, Jr.

Holotype.—USNM No. 115390.

Distribution.—There are about 20 specimens of this species in the Henryhouse collections; these are from collections 2, 3, 7, 10, 13, 15, 16, 17, 18, 22. Type locality, 18.

Genus BRACHYPRION Shaler 1865
BRACHYPRION ATTENUATA
Amsden, n. sp.
Plate 20, figures 13–20

Description.—This species has a small and delicate shell. The outline is subcircular, with the hinge line forming the greatest width of the shell. Its lateral profile is strongly concavo-convex, with the curvature of both valves uniform. The two valves are very close together so that the living chamber is small. The thickness of the pedicle shell wall is normal for a shell of this size, but the brachial is extremely thin and for this reason is rarely preserved. The surface of both valves is covered with small, rounded costellae, about 30 of these occupying a distance of 5 mm. A mature specimen is about 10 mm. wide, 8 mm. long, and 2.5 mm. deep.

The pedicle valve possesses teeth that are located on small plates on each side of the delthyrium and that extend for almost one-half the length of the hinge line. The muscle scars are only moderately deep, and a very small median septum is confined to the posterior end of the delthyrial cavity (plate 20, fig. 20). No brachial interiors have been seen.

Discussion.—The pedicle interior of this species differs somewhat from *B. leda* (genotype) as described by Caster (1939, pp. 31, 33). The denticulation of *B. attenuata* appears to be more extensive than in *B. leda;* also *B. attenuata* does not possess any dental plates.

Holotype.—USNM No. 115376.

Distribution.—This is a rather common species in the Henryhouse formation; specimens from collections 1, 2, 3, 5, 12, 13, 17, 19, 28, 29. Type locality, 2.

Genus LEPTAENISCA Beecher 1890
LEPTAENISCA IRREGULARIS
Amsden, n. sp.
Plate 20, figures 30–35

Description.—The shell of this species is always strongly concavo-convex, although its shape in both profile and outline shows many irregularities. At least a part of the life of each individual was spent with the beak area of the pedicle valve attached to some object on the sea floor; this point of attachment varies in size and shape but is commonly quite large. It is apparently this method of growth which causes the irregularities in different individuals. The hinge line is straight; on some individuals it forms the greatest width of the shell, while in others it is considerably less. The surface is marked by low, rounded, obscure costellae; these are crossed at irregular intervals by concentric growth lines. A specimen of average size measures about 10 mm. wide and 8 mm. long.

The pedicle interior is shown in plate 20, figure 32; no brachial interiors have been seen.

Discussion.—This is a much smaller species, with less strongly developed costellae, than *L. concava* (Hall 1883, pl. 15, figs. 33; Shimer and Shrock 1944, pl. 132, figs. 34, 35).

Holotype.—USNM No. 115386.

Distribution.—About 14 individuals in the Henryhouse collections 2, 3, 13, 17, 18, 29. Type locality, 2.

Genus LISSOSTROPHIA Amsden, 1949

Description.—The writer's description of this genus (1949B, p. 202) is as follows:

> Shells belonging to this genus are small with a subtriangular to subcircular outline; the hinge line is straight and forms the greatest width of the shell. In lateral profile it is strongly concavo-convex with the brachial and pedicle valves fairly close together; the curvature of both valves is uniform, there being no fold or sulcus. The pedicle beak is small and the palintrope of both valves is well-developed, that of the pedicle being slightly wider than the brachial. The surface of both valves is completely smooth except that some shells may show faint, concentric growth lines.

In the pedicle interior (pl. 20, figs. 23, 24) the diductor scars are moderately deep, elongated subparallel to one another, and separated by an elevated platform to which the adductors were presumably attached. The hinge-plate is denticulate for one-half to two-thirds its length; the delthyrium usually appears as a rather shallow notch in this plate and in some specimens it is represented by only a very slight indentation.

The brachial interior (pl. 20, fig. 25) is marked by a conspicuous elongate cardinal process which is directed posteriorly at right angles to the hinge line. The posterior half of this cardinal process is divided into two lobes which are subparallel to one another. Two thick ridges extend out from the base of the cardinal process in an antero-lateral direction. In addition, there are two relatively broad median ridges that extend from about the center of the valve almost to the base of the cardinal process. At the posterior end these are separated by a low median platform that extends in an anterior direction until it attains approximately two-thirds the distance from beak to border. In the central portion these two median ridges are separated by a valley but at their posterior end they are again separated from one another by a low ridge which is a continuation of base of the cardinal process. The brachial hinge plate is strongly denticulate for a part of its length.

Discussion.—This genus is somewhat similar to *Pholidostrophia* (Hall and Clarke 1892, p. 287) in size, shape, and lack of ornamentation, but it is not nacreous. Internally it differs from that genus in that the diductor scars of the pedicle valve are narrow and subparallel whereas in *Pholidostrophia* they are broader and semiflabellate. In the brachial interior the cardinal process of *Lissostrophia* is more erect and extends further beyond the hinge line than does that of *Pholidostrophia;* furthermore, the two median ridges are much better developed in *Lissostrophia.*

This genus differs from *Brachyprion* (Shaler 1865, p. 63; Caster 1939, pp. 31, 33) and related genera in its complete lack of radial ornamentation. Also in the pedicle interior of *Brachyprion* the muscle scars are flabellate.

The Brownsport species which was described as *Brachyprion? glabella* (Amsden 1949A, pp. 52–53, pl. 5, figs. 1–5) almost certainly belongs in this genus. This species is rather similar in its general size, shape, and lack of ornamentation to *Lissostrophia cooperi* although it should be noted that no interiors of the Brownsport species have been observed. In addition it seems quite probable that *Pholidostrophia lindenensis* (Dunbar 1920, p. 126, pl. 2, figs. 15–16) and an undescribed Waldron species also should be assigned to *Lissostrophia.*

Genotype.—*L. cooperi* Amsden.

LISSOSTROPHIA COOPERI Amsden
Plate 20, figures 21–29

Lissostrophia cooperi AMSDEN 1949B (p. 202).

Description.—The shell is small and subcircular in outline. Its hinge line is straight with the lateral extremities produced into points. The width is about equal to the length, with some specimens slightly wider than long and others slightly longer than wide. It is deeply concavo-convex, with the brachial valve rather closely following the pedicle to produce a shallow living chamber. The surface is completely smooth except for faint, irregularly spaced growth lines. A specimen of average size will measure about 6 mm. wide, 5.5 mm. long, and 3 mm. deep.

The brachial and pedicle interiors are shown on figures 23–25 of plate 20.

Discussion.—*Lissostrophia cooperi* is subcircular in outline, whereas the Brownsport species *Lissostrophia glabella* (Amsden 1949A, pp. 52–53, pl. 5, figs. 1–5; see under discussion of *Lissostrophia*) is subtriangular; furthermore, the Henryhouse species is more deeply concavo-convex than is the Brownsport species.

This is probably the species which Reeds (1911, p. 263) called *Pholidostrophia* sp.

This species is named for Dr. G. A. Cooper.

Holotype.—USNM No. 115194.

Distribution.—This is a very abundant species in the Henryhouse formation; specimens from collections 1, 2, 5, 9, 10, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 26, 27, 28, 29. Type locality, 2.

Genus FARDENIA Lamont 1935
FARDENIA REEDSI Amsden, n. sp.
Plate 17, figures 1–8

Description.—In its lateral outline and its ornamentation this species is almost identical with *F. roemeri* (Foerste 1903, p. 711; 1909, p. 82, pl. 2, figs. 27A–C; Amsden 1949A, p. 53, pl. 5, figs. 23–28). *F. reedsi* is, however, a much smaller species with individuals reaching a maximum length of 18 or 19 mm. (along the hinge line), whereas the Brownsport species may reach a width of 30 mm. Furthermore, mature specimens of *F. reedsi* are thicker than are specimens of *F. roemeri* of a comparable size. A specimen of *F. reedsi* 14 mm. wide will have a thickness of over 3 mm., whereas a specimen of *F. roemeri* which is 18 mm. wide will be a scant 2 mm. thick. This increase in thickness is attained by an increase in the degree of convexity of both valves although the pedicle still retains a slightly greater convexity.

The pedicle valve bears a shallow sulcus which begins just in front of the beaks, becoming broad and poorly defined in the anterior portion of the valve. The surface of both valves is covered with narrow, acute costellae separated by wider interspaces and crossed by fine, concentric filae. The anterior margin of a mature specimen bears eight to ten costellae in a distance of 5 mm.

There are a large number of immature specimens of this species in the collections so a fairly complete series of growth stages may be studied. These clearly show that the length increases proportionally more than does the width as the individuals approach maturity. The following series of measurements of a graded series of individuals shows this change:

width 6 mm.	length 2.5 mm.
width 10 mm.	length 4 mm.
width 14 mm.	length 8.5 mm.
width 15 mm.	length 9.5 mm.

The internal structures of both valves are like those of *F. roemeri*. The delthyrium of the pedicle valve is open except for a small, flat pseudodeltidium (?) at the apical end (pl. 17, fig. 7). The brachial valve bears a cardinal process which is bilobed at the posterior end, with the anterior ends extending forward as two diverging, erect plates; a large, arched, hoodlike plate completely encloses the cardinal process at the posterior end (pl. 17, fig. 8).

Discussion.—This is probably the species which Reeds called *Schuchertella subplanus roemeri* (1911, p. 363). This species is named for C. A. Reeds.

Holotype.—USNM No. 115302.

Distribution.—This is a common Henryhouse species, with representatives from the following collections: 1, 2, 3, 5, 7, 9, 10, 12, 13, 16, 17, 18, 19, 20, 22, 24, 26, 27, 28. Type locality, 10.

FARDENIA ATTENUATA Amsden, n. sp.
Plate 17, figures 9–14

Description.—This species in outline approaches a half-circle; the hinge line is straight and usually forms the greatest width of the shell. Its lateral profile is biconvex, with the brachial valve weakly convex, and the pedicle valve having a slightly greater convexity. The beak of the pedicle valve is small and not incurved; the well-developed palintrope is strongly apsacline. The brachial palintrope is narrow, being less than one-fourth the width of the pedicle. The brachial valve has a uniform convexity, with no trace of a sulcus. The surface of the valves is covered with low, narrow costellae, a mature specimen bearing 12 to 15 of these in a distance of 5 mm. The interspaces are relatively broad and flat and crossed by fine concentric filae which become obsolete on the costellae. A mature specimen may reach a size as great as 24 mm. wide, 17 mm. long, and 4 mm. thick.

F. attenuata has a very thin walled shell, and therefore specimens commonly show some distortion.

The pedicle interior of *F. attenuata* is similar to that of *F. reedsi*, except that the delthyrium is almost completely closed by a large, strongly arched pseudodeltidium (?), whereas in *F. reedsi* this structure is small and flattish and confined to the posterior end. Similarly the brachial interiors of these two species are somewhat alike except that *F. reedsi* has a large, arched, hoodlike structure over the posterior end of the cardinal process, while in *F. attenuata* this structure is extremely small and inconspicuous.

Discussion.—Externally this species differs from *F. reedsi* in its larger size and flatter valves; also the costellae are finer and the shell wall much thinner than in *F. reedsi*. The internal differences of these two species have already been noted.

Holotype.—USNM No. 115305.

Distribution.—This is not a common species in the Henryhouse formation; specimens from collections 9, 10, 13, 16, 17, 22, but is well represented only in 10 and 13. Type locality, 10.

FARDENIA sp.
Plate 17, figure 28

Discussion.—The Henryhouse collections include two or three fragmentary specimens of a large, thick-shelled *Fardenia*. These individuals are not complete enough to make a specific assignment; there is, however, one rather well preserved brachial interior which shows a structure similar to that of *F. reedsi* (compare figs. 8 and 28 of plate 17). It differs from *F. reedsi* in being a more massive shell with a prominent median ridge or platform extending out from the base of the cardinal process.

Distribution.—Rare; present only in collection 10.

Genus LEPTAENA Dalman 1828
LEPTAENA OKLAHOMENSIS
Amsden, n. sp.
Plate 16, figures 29–35

Description.—The adult shells of this species are over twice as wide as long. The visceral disc of the pedicle valve is gently convex to flat, and on mature specimens bears 12 to 14 concentric rugae; the brachial visceral disc is flat to slightly concave and also bears 12 to 14 rugae. These rugae are obscure near the beaks of both valves but increase in size as they approach the outer margins; the last one is abruptly deflected almost at right angles to form the trail. This trail is very strongly developed, in some specimens being equal to or greater than the width of the visceral disc. The surface of the visceral disc and trail of both valves is covered with low, rounded costellae, about 16 occupying a distance of 5 mm. The specimen shown on figures 33, 34 of plate 16 is one of the largest in the collections and is 40 mm. wide at the hinge line; the visceral disc is 15 mm. long and the trail is 12 mm. deep. Another large specimen is 35 mm. wide at the hinge line; the visceral disc is 15 mm. long and the trail 16 mm. deep.

The pedicle and brachial interiors are shown on figures 30, 32 of plate 16.

The large number of specimens of this species in the Henryhouse collections include a complete series of growth stages, from the smallest, which is less than 7 mm. wide, to the largest, which is 40 mm. wide. The unusual feature about this species is that at all stages of growth the trail is well developed; for example, a specimen 7 mm. wide will have a visceral disc which is about 4 mm. long and a trail which is 4 mm. deep. It would therefore appear that either individuals mature at different sizes, or as an individual increases in size it resorbs the trail, enlarges the visceral disc, and then secretes a new trail.

Discussion.—This species differs from *L. tennesseensis* (Amsden 1949a, pp. 54–55, pl. 5, figs. 16–22) in that it has a much better developed trail. A specimen of *L. oklahomensis*, when compared to an individual of comparable size from the Brownsport, will be seen to have a trail that is over twice as wide. This is true of all stages of growth.

The present study of the Henryhouse collections of *L. oklahomensis* showing specimens at all stages of growth would suggest that the Brownsport species *L. delicata* (Amsden 1949a, p. 55, pl. 5, figs. 11–15) is merely the immature form of *L. tennesseensis*.

Holotype.—USNM No. 115293.

Distribution.—This is a very common species in the Henryhouse formation; specimens from the following collections: 1, 2, 3, 4, 5, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 22, 27, 28. Type locality, 13.

Superfamily RHYNCHONELLACEA
Genus CAMAROTOECHIA Hall and Clarke 1892
CAMAROTOECHIA CARMELENSIS, nom. nov.
Plate 18, figures 14–18

Camarotoechia acutiplicata AMSDEN 1949A (p. 57; not Hall, 1859, p. 232).

Discussion.—This species is distinguished by its erect beak and high, sharply angular plications. The brachial fold and pedicle sulcus are strongly developed; in almost

all of the specimens the fold bears four plications and the sulcus three; however, one individual shows only three ribs on the fold and two on the sulcus. A mature shell is about 9 mm. long, 10 mm. wide, 8 mm. thick and will bear about six plications on each of the lateral slopes. The largest specimen in the collections is 10.5 mm. long, 13 mm. wide and 8 mm. thick.

There is some question regarding the reference of this species, as well as *C. altisulcata* and *C. oklahomensis*, to the genus *Camarotoechia*. These, as well as the Brownsport species *C. perryvillensis*, *C. shannonensis*, and *C. eccentrica*, resemble *C. congregata* (genotype) in the possession of dental lamellae and of a brachial cruralium supported on a median septum. The genotype differs in that the cruralium is covered with growth of the inner hinge plate. A detailed study of Silurian rhynchonellids will probably show that one or more new genera will need to be established.

Distribution.—Brownsport formation of western Tennessee and Henryhouse formation of Oklahoma. There are about 25 specimens in the following Henryhouse collections: 3, 5, 10, 11, 15, 16, 17, 18, 28.

CAMAROTOECHIA ALTISULCATA Amsden, n. sp.
Plate 18, figures 6–13

Description.—This species is subtriangular in outline, with the width considerably greater than the length. Its lateral profile is biconvex, with the pedicle valve moderately convex and the brachial strongly convex, the latter feature being due primarily to the deep fold developed on the forward half of the valve. The pedicle beak is small, sharp, and curved over the brachial; a pedicle sulcus begins 2 or 3 mm. in front of the beak and becomes deep on the anterior half of the shell. This sulcus usually bears three broad plications and is deflected at slightly over 90° to the posterior portion of the valve. The brachial valve bears a fold that begins about 3 mm. in front of the beak, becoming high and sharp on the forward half of the valve; this fold usually bears four plications. The anterior portion of the shell bears high, prominent plications that become obsolete toward the posterior end; there are four or five of these ribs on each of the lateral slopes. A specimen of average size is 9 mm. long, 13 mm. wide, and 11 mm. deep; one of the largest specimens is 10 mm. long and 14 mm. wide.

There are no well preserved pedicle interiors in the collections, but such as are present indicate that the muscle scars are not deep and the dental plates well developed. The brachial interior is shown on plate 18, figure 6. The internal characters of this species are similar to those of *C. carmelensis*.

Discussion.—This species differs from *C. acutiplicata* in its wider, more triangular outline, its more strongly developed fold and sulcus, and more incurved beak. Also the costellae of *C. altisulcata* are not as strongly developed on the anterior portion of the shell. See also under discussion of *C. carmelensis*.

Holotype.—USNM No. 115322.

Distribution.—There are about a dozen specimens of this species from collections 1, 2, 3, 4?, 5, 10, 16?, 17, 20. Type locality, 3.

CAMAROTOECHIA OKLAHOMENSIS Amsden, n. sp.
Plate 18, figures 1–5

Description.—The outline of this large species is well shown on plate 18, figures 3, 4. Its lateral profile is biconvex, with the pedicle valve shallow and rather flat and the brachial valve deep. The pedicle beak is small, pointed, and erect; a pedicle sulcus begins at about the midlength, becoming moderately deep at the anterior end and bearing about five costellae. A low fold is present on the anterior third of the brachial valve, and this bears about six costellae. The costellae are low and rounded and become indistinct toward the posterior and lateral margins; there are five or six of these on each of the lateral margins. The largest specimen in the collections is 20 mm. long, 18 mm. wide, and 12 mm. thick.

There are no well-preserved interiors in the collections. Such material as is present suggests that the internal characters of this species are similar to that of *C. perryvillensis* (Amsden 1949a, p. 56, pl. 6, figs. 1–8) with the pedicle valve possessing well-developed dental plates and a low median septum. The brachial valve has a median septum extending for about one-third the length of the valve.

Discussion.—In its general shape, erect beak and rounded costellae this species is most similar to *C. perryvillensis*. *C. oklahomenis* is, however, a much larger species with broader costellae. (See also under discussion of *C. carmelensis*.)

Holotype.—USNM No. 115321.

Distribution.—There are only nine specimens of this species in the Henryhouse collections; these are from collections 3, 12, 18. Type locality, 3.

CAMAROTOECHIA FILISTRIATA
Amsden, n. sp.
Plate 19, figures 39–44

Description.—This species is biconvex, with the brachial valve having slightly the greater convexity. The pedicle beak is blunt and erect; a pedicle sulcus begins 3 or 4 mm. in front of the beak, becoming deep on the anterior half of the valve and bearing as many as six costellae. The brachial valve bears a fold that begins about 4 mm. in front of the beak and is prominent on the anterior portion; this bears six or seven costellae. The costellae are moderately high and subangular, with about six occupying each of the lateral slopes; these costellae are crossed by concentric filae (see fig. 44, pl. 19). A mature specimen will measure about 13 mm. long, 15 mm. wide and 10 mm. deep.

Discussion.—In its general shape and ornamentation this species is similar to *C. cedarensis* (Amsden 1949a, p. 58, pl. 7, figs. 1–9); both possess the fine concentric filae in addition to the subangular plications. *C. filistriata* differs from that species in that the umbones are broader and the beak shorter and blunter.

The collections include one etched specimen that displays the internal characters fairly well. This shows that the structures of both valves are similar to if not identical with those of *C. cedarensis*. The brachial interiors of these two species differ somewhat from those of *C. carmelensis*, *C. altisulcata*, *C. oklahomensis*, *C. perryvillensis*, *C. shannonensis*, and *C. eccentrica* (see under discussion of *C. carmelensis*). In *C. cedarensis* and *C. filistriata* the brachial median septum is low, becoming thickened at the posterior end to form a platform which abuts against the base of the divided hinge plate, thus making a small and poorly defined cruralium.

Holotype.—USNM No. 115365.

Distribution.—This is not a common species in the Henryhouse formation; the collections include specimens from collections 2, 3, 7, 9, 10, 11, 13, 15, 16, 18, 20, 26. Type locality, 13.

Superfamily SPIRIFERACEA
(as here used includes all of the impunctate spire-bearers)
Genus ATRYPA Dalman 1828
ATRYPA TENNESSEENSIS Amsden
Plate 17, figures 30–36

Atrypa tennesseensis AMSDEN 1949A (pp. 62–63, pl. 9, figs. 1–9).

Discussion.—The general size and shape of the specimens from the Henryhouse formation is like that of the Brownsport individuals. The only difference is that the concentric lamellae of the Henryhouse specimens are slightly better developed; on well-preserved material, especially on young shells, these lamellae are produced forward into small protuberances as they cross the costellae. These lamellae are quite delicate and are commonly abraded so that most specimens have a relatively smooth surface; such protuberances are also present on the Brownsport individuals, but they do not appear to be as well developed.

The brachial and pedicle interiors are shown on figures 30, 34 of plate 17.

Distribution.—Brownsport formation of western Tennessee and Henryhouse formation of Oklahoma; this is an extremely abundant species in the Henryhouse and is present in the following collections: 1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 25, 26, 27, 28, 29.

ATRYPA ARCTOSTRIATA Foerste
Plate 17, figure 29

Atrypa arctostriata FOERSTE 1903 (p. 710; 1909 p. 93, pl. 2, figs. 34A, B).
Atrypa arctostriata AMSDEN 1949A (p. 63, pl. 9, figs. 10–15).

Discussion.—Only four specimens in the collections are referred to this species. These are similar to the Brownsport specimens, although the ribs may be slightly thicker, there being about 12 in a distance of 5 mm. No interiors have been seen.

Distribution.—Brownsport formation of western Tennessee and Henryhouse formation of Oklahoma; the Henryhouse specimens from collections 16, 22, 26.

Genus LISSATRYPA Twenhofel 1914
LISSATRYPA DECATURENSIS Amsden
Plate 19, figures 10–16

Lissatrypa decaturensis AMSDEN 1949A (p. 64, pl. 9, figs. 16–23).

Discussion.—This species is completely smooth except for the growth lines, which are commonly rather conspicuous. The pedicle valve is slightly deeper than the brachial and uniformly convex, although a few specimens show a slight flattening along the anterior margin of the midline. The brachial valve bears a small but distinct sulcus that begins just anterior to the beak and extends forward for one-third to one-half the length of the valve, and then disappears completely. Specimens of *L. decaturensis* from the Henryhouse formation appear to be identical with those from the Brownsport.

The brachial and pedicle interiors are shown on figures 10, 16 of plate 19.

There is some question regarding the genotype of *Lissatrypa*. In 1914 Twenhofel (pp. 31–33) proposed this genus and designated *L. atheroidea* as the type species. During this same year Holtedahl (1914, pp. 22–24, pl. 7, figs. 9–13) published a paper in which he used the name *Lissatrypa*, stating in a footnote that "The genus *Lissatrypa* is proposed by Dr. W. H. Twenhofel in the manuscript of a still unprinted work on the Ordovician and Silurian of the Anticosti Island. . . . " Holtedahl referred two species to this genus, *L. scheii* (a new species) and *L. phoca* (Salter). He noted that *L. atheroidea* of Twenhofel was the genotype, but if Twenhofel's paper postdates Holtedahl's then this species is a nomen nudum and either *L. scheii* or *L. phoca* must be selected as the type species.

The Henryhouse species appear to be congeneric with *L. atheroidea*; *L. scheii* and *L. phoca* are larger and more strongly convex and may belong with the genus *Atrypella*.

Distribution.—Brownsport formation of western Tennessee and Henryhouse formation of Oklahoma. There are a fairly large number of specimens in collection 6; also a few specimens from 4, 5, 23, 25.

EXPLANATION OF PLATE 17

FIGS. *1–8*—*Fardenia reedsi* Amsden, n. sp. *1*, *2*, *4*, *6*, pedicle, brachial, posterior and lateral views of the holotype (×2). In the posterior view of fig. *4* the pedicle valve is down. Coll. 10. USNM 115302. *3*, brachial exterior (×1). Coll. 9. USNM 115299. *5*, pedicle exterior (×2). Coll. 9. USNM 115300. *7*, pedicle interior (×2). Coll. 10. USNM 115303. *8*, brachial interior (×2). Coll. 9. USNM 115301. (p. 84)

9–14—*Fardenia attenuata* Amsden, n. sp. *9*, brachial exterior (×2). Coll. 13. USNM 115308. *10*, pedicle interior (×2). The protrusion on the right hand side of this valve appears to be a secondary deposition of shell material, probably representing a position where the shell had been damaged. Coll. 10. USNM 115304. *11*, *13*, posterior (×2) and pedicle (×1) views of the holotype. In the posterior view of fig. *11* the pedicle valve is down. Coll. 10. USNM 115305. *12*, brachial view (×1). Coll. 10, USNM 115306. *14*, brachial interior (×2). Coll. 10. USNM 115307. (p. 84)

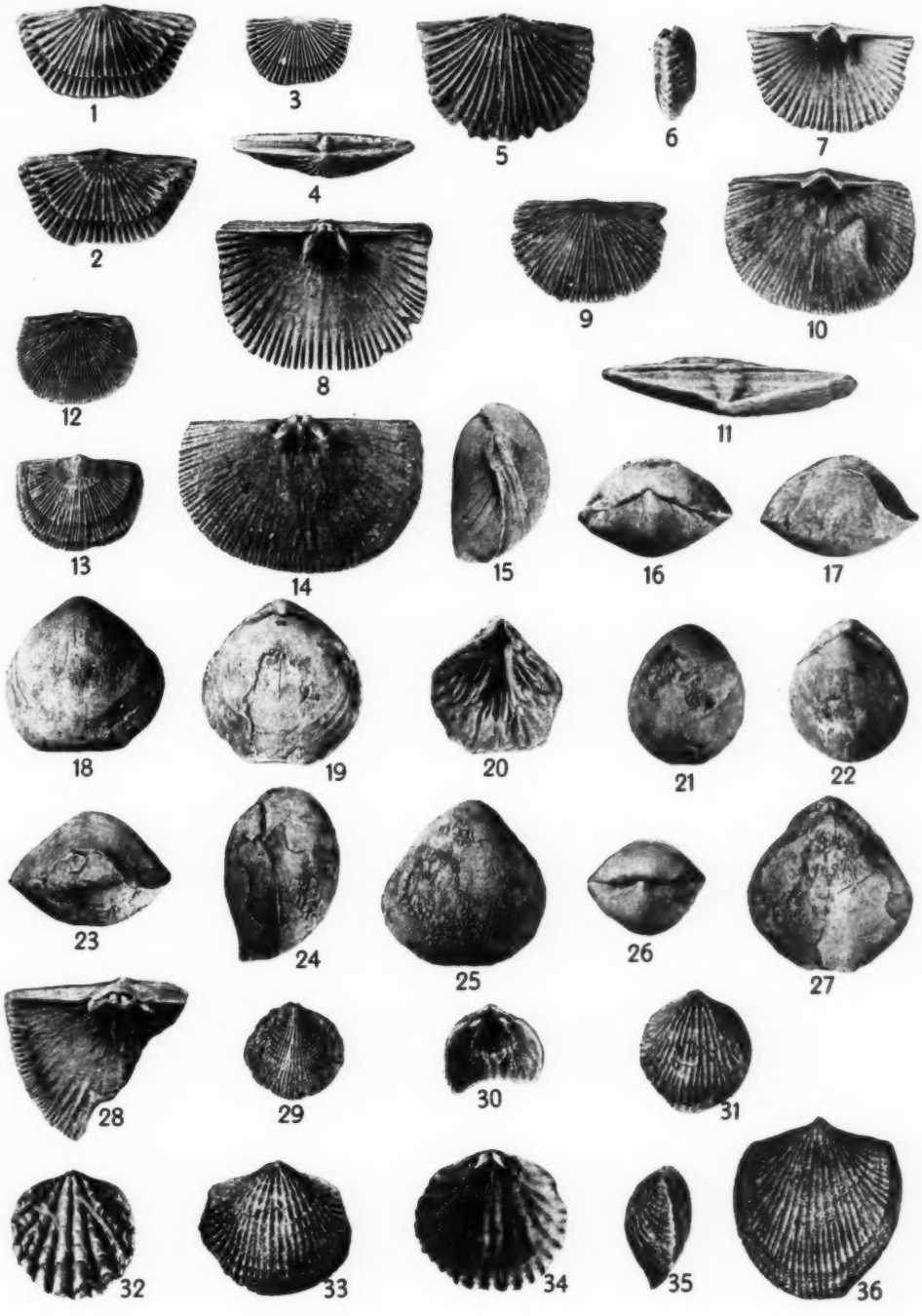
15–20—*Meristina roemeri* Foerste. *15–19*, lateral, posterior, anterior, pedicle and brachial views of the same specimen (×1). Coll. 3. USNM 115309. *20*, pedicle interior (×1). Coll. 18. USNM 115310. (p. 94)

21–27—*Merista oklahomensis* Amsden, n. sp. *21*, *22*, *26*, pedicle, brachial and posterior views of same specimen (×1). Coll. 10. USNM 115312. *23–25*, *27*, anterior, lateral, pedicle and brachial views of the holotype (×1). Coll. 3. USNM 115311. (p. 93)

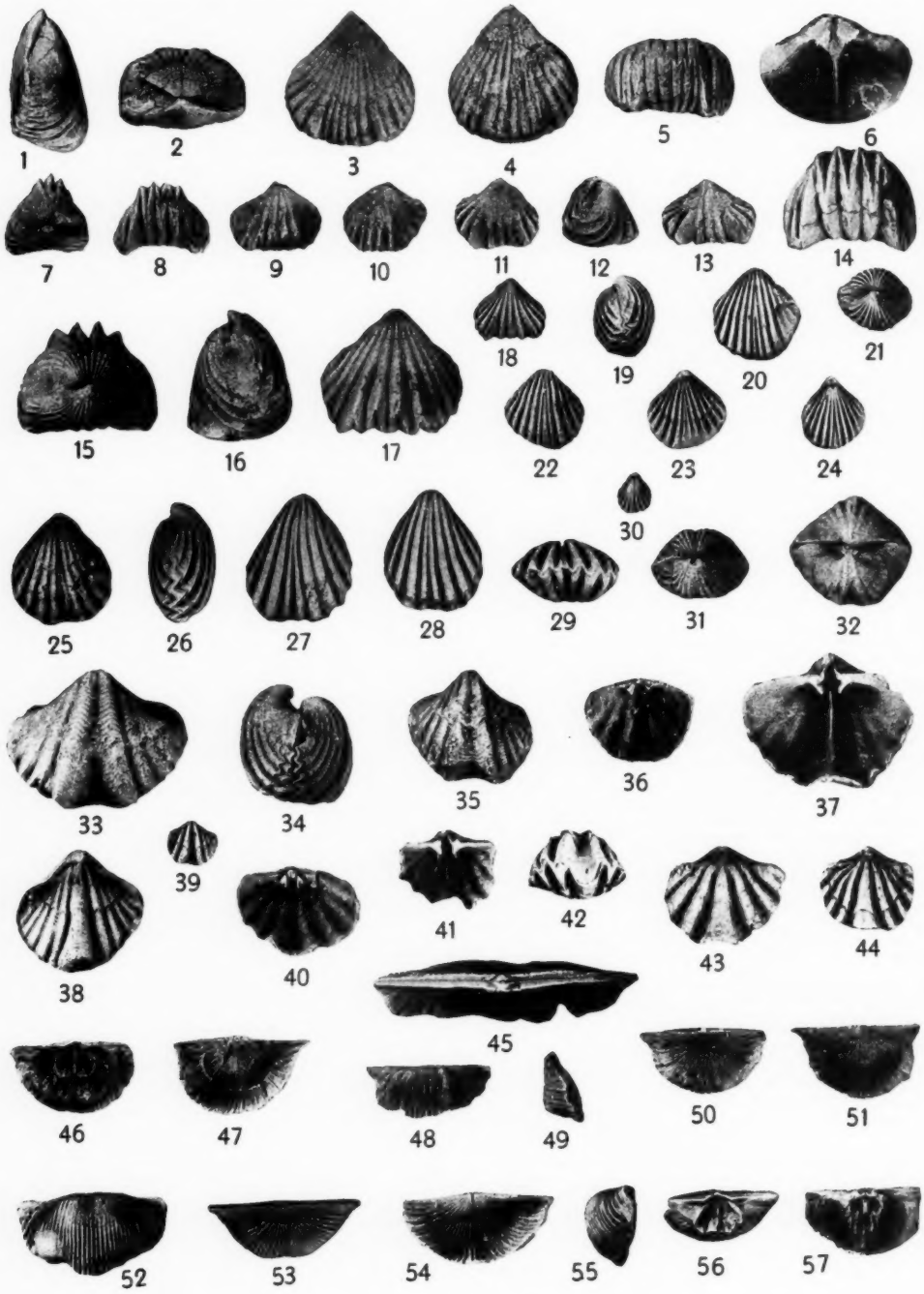
28—*Fardenia* sp., brachial interior (×1). Coll. 10. USNM 115313. (p. 85)

29—*Atrypa arctostriata* Foerste, pedicle valve (×1). Coll. 16. USNM 115314. (p. 87)

30–36—*Atrypa tennesseensis* Amsden. *30*, pedicle interior (×1). Coll. 2. USNM 115316. *31*, *35*, brachial and lateral views of the same specimen (×1). Coll. 7. USNM 115319. *32*, pedicle view of a small individual (×2). Coll. 2. USNM 115317. *33*, brachial exterior (×1). Coll. 16. USNM 115315. *34*, interior view of a small brachial valve (×2). Coll. 2. USNM 115318. *36*, pedicle view of a large individual (×1). Coll. 18. USNM 115320. (p. 87)



Amsden, Oklahoma Henryhouse formation brachiopods



Amsden, Oklahoma Henryhouse formation brachiopods

LISSATRYPA HENRYHOUSENSIS Amsden, n. sp.
Plate 19, figures 32–38

Description.—This species has an outline similar to that of *L. decaturensis*. The lateral profile is moderately strongly biconvex, with the pedicle valve having the greater convexity. The pedicle valve is evenly convex and has a small beak which is incurved over the brachial. There is no trace of any sulcus on the brachial valve, and the surface of both valves is smooth except for concentric growth lines. One of the largest specimens in the collections is 10 mm. long, 11 mm. wide, and 5 mm. thick.

Etched specimens of the interiors of both valves in the collection are not very well preserved, but they clearly show this species to have internal characters similar to those of *L. decaturensis*, although the cardinal process is somewhat more massive and the sockets larger in *L. decaturensis*.

Discussion.—This species is similar in its size and general shape to *L. decaturensis*. It differs in that *L. henryhousensis* has no trace of a brachial sulcus and is also more strongly biconvex.

Holotype.—USNM No. 115362.

Distribution.—There are about 18 specimens of this species in the Henryhouse collections 10, 12, 16. Type locality, 12.

Genus NUCLEOSPIRA Hall 1859
NUCLEOSPIRA CONCENTRICA Hall
Plate 19, figures 17–24

Nucleospira concentrica HALL 1859 (p. 222, pl. 28B, figs. 15–19; Hall and Clarke 1894, pl. 48, fig. 7).

Description.—The outline of this small species is subcircular except for the anterior margin, which is straight to faintly lobate. In lateral profile it is biconvex, with the pedicle valve having slightly greater convexity. The pedicle beak is small and only

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EXPLANATION OF PLATE 18

FIGS. *1–5—Camarotoechia oklahomensis* Amsden, n. sp. *1–5*, lateral, posterior, pedicle, brachial and anterior views of the holotype (×1). Coll. 3. USNM 115321 (p. 86)

6–13—Camarotoechia altisulcata Amsden, n. sp. *6*, interior view of the posterior end of a brachial valve (×3). Coll. 17. USNM 115324. *7, 10, 11, 12*, posterior, brachial, pedicle and lateral views of the same specimen (×1). Coll. 1. USNM 115323. *8, 9, 13*, anterior, brachial and posterior views of the holotype (×1). In fig. *8* the pedicle valve is down. Coll. 3. USNM 115322. (p. 86)

14—18—Camarotoechia carmelensis Amsden. *14–18*, anterior, posterior, lateral, brachial (×2) and pedicle (×1) views of the same specimen. Coll. 17. USNM 115325. (p. 85)

19–24—Homoeospira subgibbosa Amsden, n. sp. *19, 21–23*, lateral, posterior, pedicle and brachial views of the holotype (×1). Coll. 10. USNM 115326. *20*, pedicle view of a slightly larger individual (×1). Coll. 16. USNM 115327. *24*, brachial view of another specimen (×1). Coll. 18. USNM 115392. (p. 95)

25–31—Homoeospira foerstei Amsden, n. sp. *25, 31*, brachial and posterior views of the same specimen (×3). Coll. 22. USNM 115328. *26, 28, 30*, lateral, pedicle (×3) and brachial (×1) views of the holotype. Coll. 17. USNM 115329. *27, 29*, pedicle and anterior views of an individual (×3). In fig. *29* the pedicle valve is down. Coll. 17. USNM 115330. (p. 94)

32–38—Delthyris kozlowskii Amsden, n. sp. *32, 34, 35, 38*, posterior, lateral, pedicle and brachial views of the holotype (×1). Coll. 16. USNM 115331. *33*, pedicle view of a slightly smaller individual (×2). Coll. 2. USNM 115333. *36*, interior view of a small brachial valve (×3) Coll. 10. USNM 115332. *37*, pedicle interior (×2). Coll. 2. USNM 115334. (p. 91)

39–44—Howellella henryhousensis Amsden, n. sp. *39, 42, 44*, pedicle (×1), anterior and brachial (×2) views of the holotype. In fig. *42* the pedicle valve is up. Coll. 9. USNM 115335. *40*, brachial interior (×2). Coll. 17. USNM 115336a. *41*, pedicle interior (×2). Coll. 17. USNM 115336b. *43*, brachial view of a smaller individual (×3). Coll. 17. USNM 115337. (p. 92)

45–51—Strophonella alterniradiata Amsden, n. sp. *45*, posterior view of the holotype (×2). Pedicle valve down. Coll. 7. USNM 115340. *46*, pedicle interior (×1). Coll. 16. USNM 115338. *47*, pedicle view of the holotype (×1) (same specimen shown in fig. 45). *48–50*, anterior, lateral and brachial views of an individual (×1). Coll. 2. USNM 115341. *51*, pedicle view (×1). Coll. 22. USNM 115339. (p. 80)

52–57—Strophonella prolongata Foerste. *52, 53, 55*, anterior, brachial and lateral views of the same individual (×1). Coll. 2. USNM 115342. *54*, pedicle view of another individual (×1). Coll. 2. USNM 115343. *56*, pedicle interior (×1). Coll. 2. USNM 115344. *57*, brachial interior (×1). Coll. 2. USNM 115345. (p. 79)

slightly hooked over the brachial valve; the uniform curvature of the pedicle valve is broken only by a shallow, narrow, poorly defined sulcus, beginning in front of the beak and extending to the anterior margin. A corresponding brachial sulcus begins in front of the beak and extends to the forward margin. The sulci of both valves, although consistently present, are not conspicuous and often consist of merely a flattening along the midline; the straight or faintly lobed anterior margin is produced by the forward junction of the brachial and pedicle sulci. The surface of the shell is smooth except for extremely fine spines, which are only rarely preserved. A specimen of average size is 4.5 mm. long, 4.5 mm. wide, and 2.5 mm. thick.

The internal characters of both valves appear to be typical for this genus (pl. 19, figs. 17–18). The spires have not been observed.

Discussion.—The Henryhouse specimens appear to agree with Hall's description and illustrations of the Brownsport individuals.

Distribution.—Brownsport formation of western Tennessee and Henryhouse formation of Oklahoma. In Henryhouse collections: 5, 9?, 10, 13, 15, 16, 17, 20, 22, 27. It is abundant only in collection 17.

Genus COELOSPIRA Hall 1863
COELOSPIRA SAFFORDI (Foerste)
Plate 19, figures 25–31

Anoplotheca (*Coelospira*) *saffordi* FOERSTE 1903 (p. 709; 1909, p. 89, pl. 1, fig. 6).
Coelospira saffordi AMSDEN 1949A (p. 65, pl. 10, figs. 1–5).

Discussion.—Specimens of this small species are rather common in the Henryhouse and appear to be similar in all respects to those from the Brownsport. The pedicle valve has a low fold that on mature specimens usually bears five costellae at the front end, although some individuals show only three. The brachial sulcus, which begins just behind the beaks, becomes rather deep at the anterior end and on mature specimens commonly bears four costellae.

The pedicle interior is shown on figure 27 of plate 19 and the brachial interior (minus the spires) on figure 26 of plate 19.

Distribution.—Brownsport formation of western Tennessee; Henryhouse formation of Oklahoma. Specimens from the following collections: 1, 2, 3, 4, 6, 11, 13, 14, 16, 17, 22, 26, 28, 29.

Genus NANOSPIRA Amsden

Description.—This genus was described by the writer in 1949b (p. 203). The only known species is the genotype, *N. parvula*, which has an extremely small, subcircular shell. It has a strongly convex pedicle valve and a brachial valve which is flattish to slightly concave. The pedicle valve has a smooth, even curvature and a small pointed beak. The brachial sinus is narrow and distinct on the posterior portion of the valve, becoming broad toward the anterior end. The exterior of both valves is completely smooth, except for concentric growth lines.

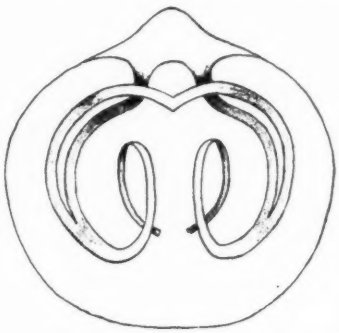


FIG. 1—Brachidium of *Nanospira parvula* viewed from the ventral side.

In the pedicle interior (plate 19, fig. 2) the teeth are prominent and attached directly to the wall of the valve. A median septum or platform extends for about one-half the length of the valve and is V-shaped in cross section. This begins as a low ridge at the posterior end, but becomes increasingly broader and higher toward the central part of the valve; its anterior end is slightly excavated and the sides are produced forward for a short distance as low ridges.

The interior of the brachial valve (minus the spire) is well shown on plate 19, figure 5. The brachidium of this genus is rather unusual and the writer is indebted to Dr. G. A. Cooper for preparing specimens to show this structure. As shown on text figure 1 the spire is abbreviated, consisting of less

than one volution with the apices medially directed. The jugum is unusual in that each of its branches comes off from the anterior portion of the spires; these continue posteriorly as separate structures which are outside of and parallel to the main branches of the spires. Near the posterior end of the valve they cross over the descending lamellae and turn forward before uniting. The spire appears to be strongly spinose.

This genus has a smooth exterior like that of *Glassia* (Davidson 1881, p. 11). The spires of *Nanospira* are directed as they are in *Glassia*, but have many less coils; the jugum is different, originating much further forward than in *Glassia*. Also *Glassia* appears to lack the strong median platform that is present in the pedicle valve of *Nanospira*. *Protozyga* (Hall & Clarke 1894, p. 151) has a simple spire like that of *Nanospira* but differs in the nature of its jugum and in having dental plates in the pedicle valve. *Cyclospira* (Hall and Clarke 1984, p. 146) differs in its biconvex profile and strong ventral sulcus. The jugum of *Cyclospira* is unknown.

The only species which is here referred to this genus is *N. parvula*, from the Henryhouse.

NANOSPIRA PARVULA Amsden
Plate 19, figures 1–9; text figure 1

Nanospira parvula AMSDEN 1949B (p. 203).

Description.—This species has a very small shell, with the width about equal to the length and a short hinge line. It has a strongly convex pedicle valve and a weakly convex to weakly concave brachial valve. The pedicle beak is small and strongly curved over the dorsal but not in conjunction with it; along the midline of the pedicle valve the curvature is sharp, with the shell sloping uniformly away from here to the lateral and anterior margins. There is a brachial sulcus which is narrow at the posterior end but which becomes broad at the anterior end; on the posterior half of the brachial valve, where this sulcus is narrow and confined to the midline, the valve retains a slight convexity, but toward the anterior end, where it broadens out so that it occupies almost the entire width of the shell, this part of the valve becomes slightly concave. The surface is completely smooth except for growth lines, these being best developed on the anterior half of the shell. A specimen of average size is about 3.5 mm. long, 3.5 mm. wide. and 2 mm. thick. The brachial and pedicle interiors have already been described.

Discussion.—*N. parvula* is the only known representative of this genus and has been identified only from the Henryhouse formation.

Holotype.—USNM No. 115195.

Distribution.—Specimens of this species are common in the Henryhouse formation; the following collections represented: 1, 2, 3, 5, 10, 13, 14, 16, 17, 19, 22, 27, 28, 29. It is especially common at 5, 13, 17. Type locality, 29.

Genus DELTHYRIS Dalman 1828
DELTHYRIS KOZLOWSKII Amsden, n. sp.
Plate 18, figures 32–38

Description.—The width of this rather large species is slightly greater than the length. Both valves are strongly convex, with the pedicle valve having slightly the greater convexity. The pedicle beak is long with its posterior tip sharply hooked towards the brachial. A prominent sulcus on the pedicle valve begins just behind the beak, becoming deep toward the anterior margin; on each side of this sulcus there are four to five plications, those next to the sulcus being sharp and high and becoming progressively weaker towards the lateral margins. The brachial valve bears a fold that begins just behind the beak and becomes broad and high at the front end; four or five plications occupy each side of this fold, with those on the lateral margins rather low and obscure. The surface of both valves is covered with well developed, concentric lamellae that bear slender, long spines. The largest specimen in the collections is 24 mm. wide, 22 mm. long and 16 mm. thick.

Well-developed dental plates in the pedicle interior are separated by a high, median septum that extends for almost half the length of the valve (pl. 15, fig. 37). The brachial interior is shown on plate 18, figure 36.

Discussion.—This is a much larger species than *D. saffordi* (Hall 1859, p. 203, pl. 28,

figs. 2a, b, c, e, f; Amsden 1949a, p. 65, pl. 11, figs. 10–20), from the Brownsport formation. Also the concentric lamellae are more strongly developed on *D. kozlowskii*.

Holotype.—USNM No. 115331.

Distribution.—Henryhouse formation of Oklahoma; specimens from the following collections: 1, 2, 3, 5, 9?, 10, 13, 15, 16, 17, 18, 26. Common only in 2. Type locality, 16.

Genus HOWELLELLA Kozlowski 1946
(equals *Crispella* of Kozlowski 1929)

HOWELLELLA HENRYHOUSENSIS
Amsden, n. sp.
Plate 18, figures 39–44

Description.—The shape of this species is well shown in the illustrations. It is biconvex, with the pedicle valve having much the greater convexity. The pedicle palintrope is relatively large and strongly apsacline; the pedicle beak is only slightly hooked at its posterior end. A well-developed pedicle sulcus extends from beak to border; a mature specimen bears four plications on each side of this sulcus and these remain sharp and well-defined toward both the lateral and posterior margins. The brachial valve bears a fold that is about twice as wide as the plications on each side of it; about four such plications occupy each lateral slope and these remain sharply defined toward the lateral and posterior margins. The surface of both valves is covered with closely spaced concentric lamellae, with each lamella bearing small spines. A mature specimen is about 7 mm. long, 6 mm. wide, and 4 mm. thick.

The pedicle interior has well-developed dental plates but no median septum (plate 18, fig. 41). There is a cardinal process in the brachial valve as shown in plate 18, figure 40.

Discussion.—This is a somewhat smaller species than *H. crispa* (Hisinger 1826; Shimer and Shrock 1944, p. 327, pl. 125, figs. 18–20) with more sharply defined plications. Externally it differs from *Delthyris kozlowskii* in its smaller size, less sharply hooked pedicle beak and more subangular plications. Internally the pedicle valve of *H. henryhousensis* lacks a median septum.

Holotype.—USNM No. 115335.

EXPLANATION OF PLATE 19

FIGS. *1–9—Nanospira parvula* Amsden. *1*, *8*, *9*, pedicle, anterior and posterior views of the same specimen (×5). In figs. *8* and *9* the pedicle valve is up. Coll. 17. USNM 115347. *2*, pedicle interior (×5). Coll. 17. USNM 115348. *3*, *4*, *6*, brachial (×5), pedicle (×1) and lateral (×5) views of the holotype. Coll. 29. USNM 115195. *5*, brachial interior (×5). Coll. 17. USNM 115349. *7*, brachial view of another specimen (×5). Coll. 2. USNM 115346. (p. 91)

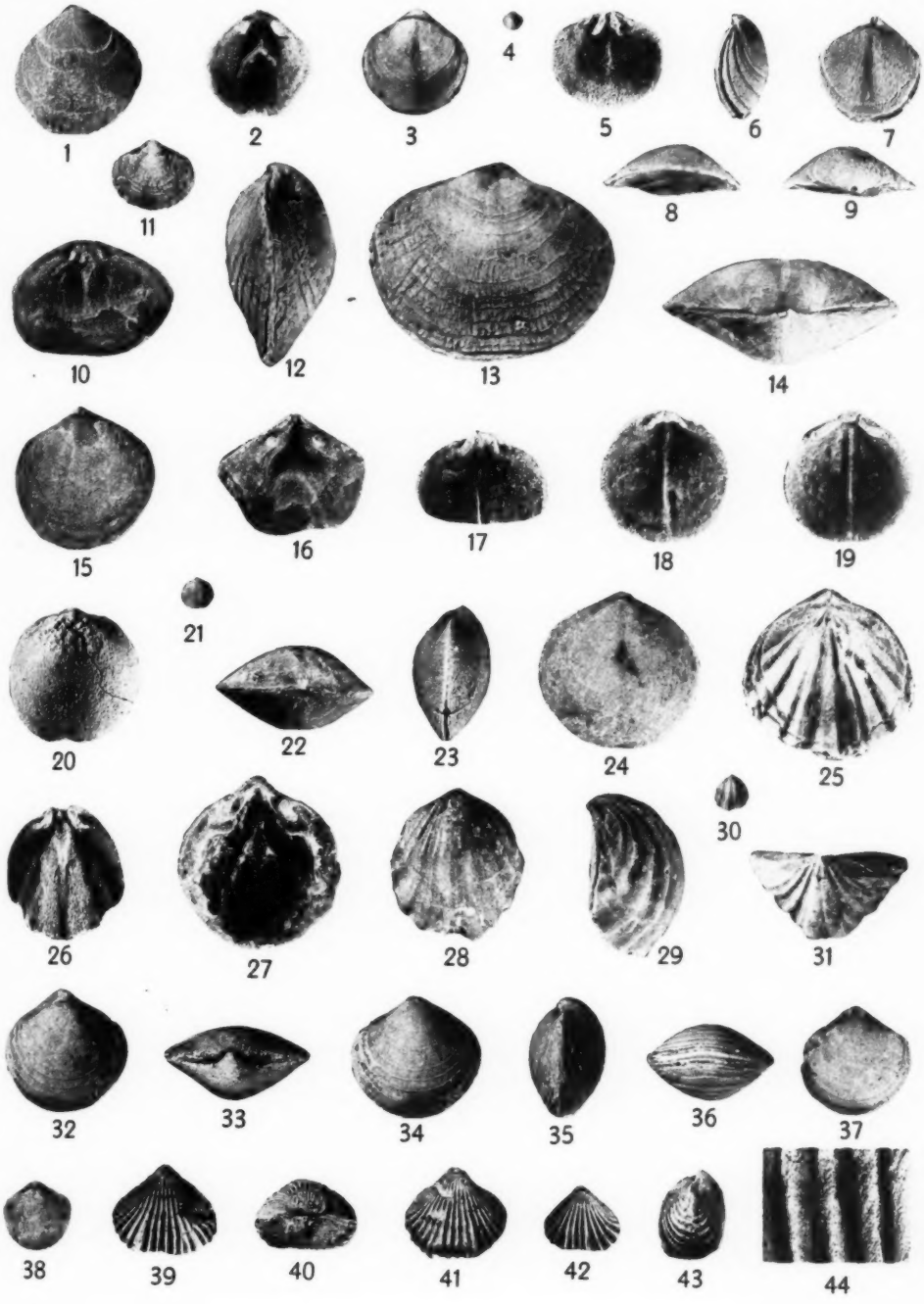
10–16—Lissatrypa decaturensis Amsden. *10*, brachial interior (×3). Coll. 6. USNM 115353. *11–14* pedicle (×1), lateral, brachial and posterior (×3) views of the same specimen. In fig. *14* the pedicle valve is down. Coll. 6. USNM 115354. *15*, brachial view of a smaller individual (×3). Coll. 6. USNM 115355. *16*, pedicle interior (×3). Coll. 6. USNM 115356. (p. 88)

17–24—Nucleospira concentrica Hall. *17*, oblique interior view of a brachial valve (×5). Coll. 17. USNM 115350. *18*, the same brachial interior as that shown in fig. *17* viewed directly from above (×5). *19*, interior view of a pedicle valve (×5). Coll. 17. USNM 115351. *20*, *23*, brachial and lateral views of the same specimen (×5). Coll. 17. USNM 115352. *21*, *22*, *24*, pedicle (×1), posterior and brachial (×5) views In fig. *22* the pedicle valve is down. Coll. 27. USNM 115357. (p. 89)

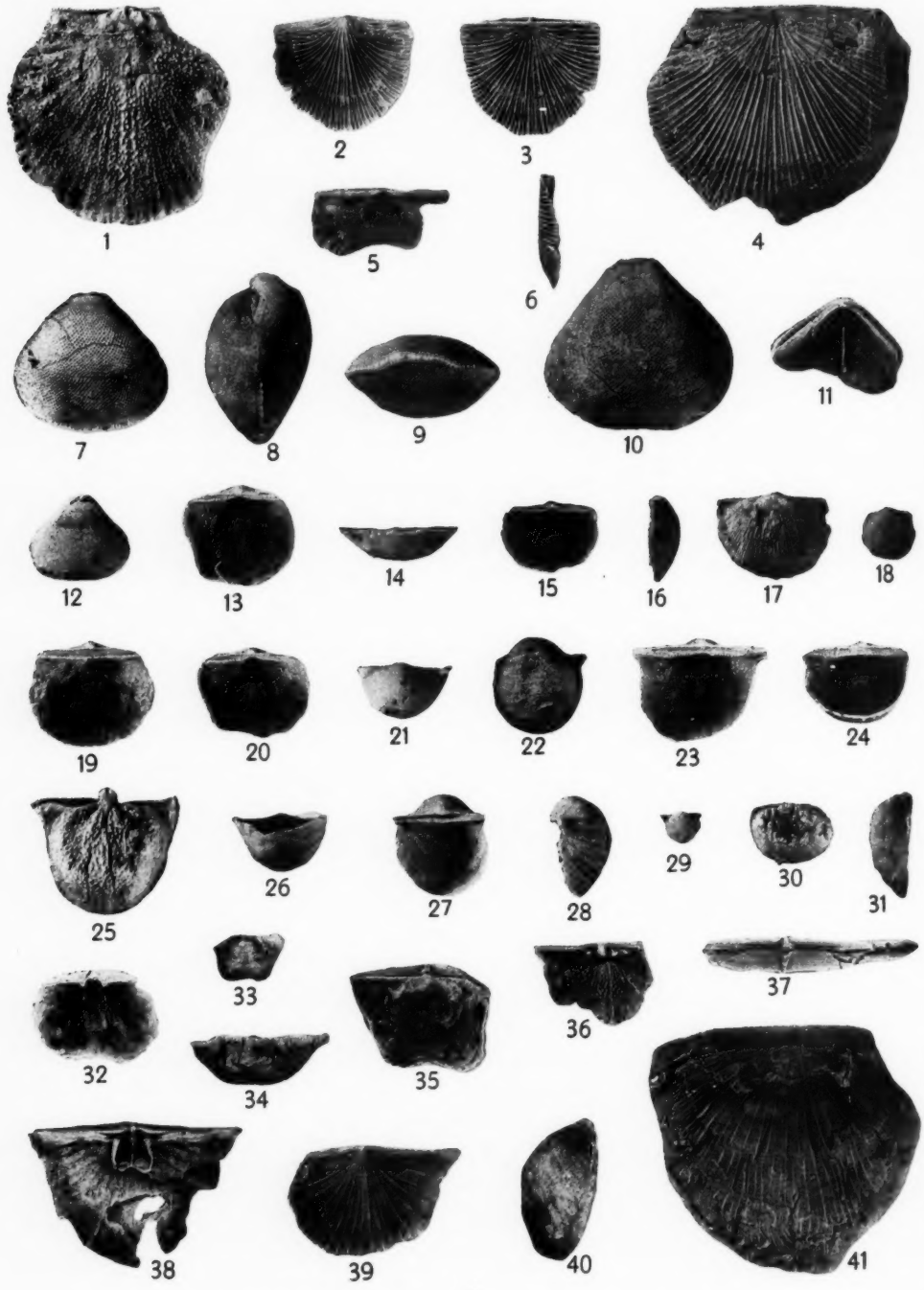
25–31—Coelospira saffordi (Foerste). *25*, *29–31*, brachial (×5), lateral (×5), pedicle (×1) and posterior (×5) views of the same specimen. Coll. 2. USNM 115358. *26*, brachial interior (×5). Coll. 14. USNM 115360. *27*, pedicle interior (×5). Coll. 2. USNM 115359. *28*, pedicle exterior (×5). Coll. 29. USNM 115361. (p. 90)

32–38—Lissatrypa henryhousensis Amsden, n. sp. *32*, *34–36*, brachial, pedicle, lateral and anterior views of the holotype (×2). In fig. *36* the pedicle valve is down. Coll. 12. USNM 115362. *33*, *38*, posterior (×2) and brachial (×1) views of another specimen. Coll. 12. USNM 115363. *37*, brachial view of a small individual (×3). Coll. 10. USNM 115364. (p. 89)

39–44—Camarotoechia filistriata Amsden, n. sp. *39–41*, *43*, pedicle, posterior, brachial and lateral views of the holotype (×1). Coll. 13. USNM 115365. *42*, brachial view of a smaller individual (×1). Coll. 3. USNM 115367. *44*, enlarged view of the surface (×5), showing the fine concentric filae. USNM 115366. (p. 87)



Amsden, Oklahoma Henryhouse formation brachiopods



Amsden, Oklahoma Henryhouse formation brachiopods

Distribution.—The Henryhouse collections include specimens from collections 2, 5, 9, 10, 13, 16, 17, 22. It is not common in any of these. Type locality, 9.

Genus MERISTA Suess 1851

MERISTA OKLAHOMENSIS Amsden, n. sp.

Plate 17, figures 21–27

Description.—This species has a biconvex shell with the pedicle valve having the greater convexity. The pedicle beak is hooked and strongly incurved over the brachial. The posterior half of the pedicle valve is strongly and uniformly convex, but at about the midlength of the valve a sulcus appears; this sulcus continues to the anterior margin more as a flattening in the curvature than as an actual depression. A corresponding fold on the brachial valve appears in the anterior third of the valve and becomes pronounced at the forward margin. The union of this brachial fold and pedicle sulcus causes the anterior margin to be produced into a tongue. The surface of the shell is smooth except for faint, irregularly spaced growth lines. This is a rather large species with mature specimens attaining a length and width of 25 mm. and a thickness of 17 mm.

Etched specimens of this species (minus the spire) show that it has an internal structure which is similar to that of *Merista tennesseensis* (Amsden 1949A, pp. 66–67, pl. 11, figs. 1–9).

Discussion.—*Merista oklahomensis* is a larger species than *Merista tennesseensis* (Hall and Clarke, 1894, pp. 71, 365, pl. 42, figs. 1–6; Amsden 1949A, p. 66), with the Henryhouse specimens attaining a length 8 or 9 mm. greater than that of the Brownsport species. Immature specimens of this species are similar to mature specimens of *M. tennesseensis* except that *M. oklahomensis* is commonly somewhat more elongate. As *M. oklahomensis* approaches maturity its

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EXPLANATION OF PLATE 20

FIGS. *1–6*—*Strophonella laxiplicata* Foerste. *1*, brachial interior (×2). Coll. 12. USNM 115369. *2*, *3*, *6*, pedicle, brachial and lateral views of a small individual (×1). Coll. 5. USNM 115370. *4*, brachial view of one of the largest specimens in the collections (×1). Coll. 3. USNM 115368. *5*, pedicle interior (×1). Coll. 10. USNM 115371. (p. 81)

7–12—*Dictyonella gibbosa* (Hall). *7*, *9*, pedicle and anterior views (×2). In fig. *9* the pedicle valve is down. Coll. 2. USNM 115373. *8*, *10*, lateral and pedicle views of an individual (×2). Coll. 3. USNM 115372. *11*, brachial interior (×2). USNM 115374. *12*, brachial view of the same specimen shown in figs. *8*, *10* (×1). (p. 78)

13–20—*Brachyprion attenuata* Amsden, n. sp. *13*, *20*, interior views of the same pedicle valve (×2). In fig. *13* the valve is seen directly from above; in fig. *20* the view is oblique, looking down into the delthyrial cavity and showing the small median septum at the posterior end. Coll. 2. USNM 115375. *14*, *18*, *19*, posterior (×2), pedicle (×1) and brachial (×2) views of the holotype. Coll. 2. USNM 115376. *15*, pedicle interior (×2). Coll. 2. USNM 115377. *16*, *17*, lateral and pedicle views of an individual (×2). Coll. 2. USNM 115378. (p. 82)

21–29—*Lissostrophia cooperi* Amsden. *21*, *22*, *26–28*, posterior, pedicle, anterior, brachial and lateral views of the holotype (×2). In figs. *21* and *26* the pedicle valve is down. Coll. 2. USNM 115194. *23*, pedicle interior viewed directly from above (×3). Coll. 2. USNM 115379. *24*, oblique view looking down into the delthyrial cavity of another pedicle valve (×3). Coll. 2. USNM 115380. *25*, brachial interior (×3). Coll. 17. USNM 115382. *29*, pedicle view (×1). Coll. 13. USNM 115381. (p. 83)

30–35—*Leptaenisca irregularis* Amsden, n. sp. *30*, pedicle view of a small specimen showing the irregular area of attachment around the beak (×3). Coll. 17. USNM 115383. *31*, lateral view of another specimen (×2). Coll. 17. USNM 115384. *32*, pedicle interior (×2). Coll. 2. USNM 115385. *33–35*, pedicle (×1), posterior and brachial (×2) views of the holotype. Coll. 2. USNM 115386. (p. 82)

36–41—*Strophonella loeblichi*, Amsden, n. sp. *36*, brachial interior (×2). Coll. 22. USNM 115389. *37*, posterior view of the hinge of the holotype (×1). Pedicle valve down. Coll. 18. USNM 115390. *38*, pedicle interior (×1). Coll. 7. USNM 115387. *39*, pedicle view of a small individual (×1). Coll. 7. USNM 115388. *40*, lateral view (×1). Coll. 15. USNM 115391. *41*, brachial view of the holotype (×1). This is the same specimen as that shown in fig. *37*. (p. 81)

width becomes about equal to its length and it comes to resemble *Meristina roemeri* closely, so that it is difficult to separate the two; generally the pedicle sulcus and brachial fold are somewhat better developed on *M. roemeri*.

Holotype.—USNM No. 115311.

Distribution.—There are about 45 specimens of this species in the Henryhouse collections 1, 2, 3, 4, 5, 9, 10, 12, 13, 15, 16, 17, 18, 27. Type locality, 3.

Genus MERISTINA Hall 1867
MERISTINA ROEMERI Foerste
Plate 17, figures 15–20

Meristina maria roemeri FOERSTE (1909, p. 88, pl. 2, figs. 29A–B).

Discussion.—Most of the specimens of this species from the Henryhouse are subtrigonal in outline, with the width equal to or greater than the length. Some specimens, however, do show variation from this outline and may be somewhat elongate, with the width less than the length. The pedicle beak is always tightly incurved over the brachial valve and the anterior third of the pedicle valve is flattened into a sulcus and deflected almost at a right angle to the plane of the posterior portion. A corresponding strong fold appears on the forward third of the brachial valve. The surface is smooth except for indistinct growth lines.

The Henryhouse specimens appear to be similar to typical Brownsport specimens, although they may be somewhat smaller, with the thickness relatively greater in proportion to the width. The specimen figured on plate 17, figures 15–19, is 23 mm. long, 33 mm. wide, and 15 mm. thick; the largest specimen in the collection is 32 mm. long, 31 mm. wide and 27 mm. thick. The pedicle interior is shown on plate 17, figure 20.

As noted by Foerste *M. roemeri* is more triangular in outline than the Waldron species *M. maria*. This species is externally similar to *Merista oklahomensis* (see discussion of that species).

Distribution.—Brownsport formation of western Tennessee; Henryhouse formation of Oklahoma. This is not a common species in the Henryhouse; specimens in collections 3, 12, 18, 24.

Superfamily PUNCTOSPIRACEA
Genus HOMOEOSPIRA Hall and Clarke 1894
HOMOEOSPIRA FOERSTEI Amsden, n. sp.
Plate 18, figures 25–31

Description.—This shell is biconvex, with the pedicle valve having the greater convexity. The pedicle beak is rather long and slightly hooked over the brachial valve; a shallow, poorly defined sulcus begins just in front of the beak and extends to the anterior margin where it commonly bears two costellae. The brachial valve also bears a shallow sulcus which at the anterior margin usually bears one costella. The union of the brachial and pedicle sulci at the front causes the anterior margin to be slightly lobate. For a shell of this size the costellae are broad and prominent; these are separated from one another by broad interspaces which are crossed by faint, concentric filae. A mature specimen of average size bears about five costellae on each side of the ventral and of the dorsal sulci; such a specimen will be about 5.5 mm. long, 4.5 mm. wide, and 3 mm. thick. One of the largest specimens in the collections is 8 mm. long. 6.5 mm. wide, and 5 mm. thick. Shell punctate.

The brachial and pedicle interiors appear to be typical for this genus. In the pedicle valve the delthyrium is closed by flat deltidial plates; the median septum of the brachial valve is high and extends for about one-half the length of the valve. The spires have not been observed.

Discussion.—This species is more elongate than *H. beecheri* (Foerste 1903, p. 709; 1909, p. 90, pl. 1, figs. 8A, B; Amsden 1949A, p. 68, pl. 10, figs, 11–15) and has less prominent costellae. Also *H. foerstei* commonly bears only one rib on the brachial sulcus whereas *H. beecheri* bears two.

Holotype.—USNM No. 115329.

Distribution.—This is a common species in the Henryhouse formation with specimens from collections 1, 2, 3, 5, 9, 10, 13, 15, 16, 17, 22, 27, 28. It is most abundant in 5, 17, 22. Type locality, 17.

HOMOEOSPIRA SUBGIBBOSA Amsden, n. sp.
Plate 18, figures 19–24

Description.—The greatest width of this shell is developed at approximately the middle of the valves and is about equal to the length; its hinge line is very short. It is rather strongly biconvex, with the pedicle valve having the greater convexity. The pedicle beak is long, rounded, and slightly hooked over but not in conjunction with the brachial. On most specimens the pedicle valve is uniformly convex although some individuals do exhibit a slight flattening along the midline of the anterior portion of the valve. There is no trace of any sulcus on the brachial valve which is evenly and strongly convex. The surface is covered with prominent, rounded costae which are crossed by concentric growth lines. The anterior margin of a mature specimen bears five or six costae in a distance of 5 mm. An average size specimen is about 13 mm. long, 13 mm. wide, and 8 mm. thick; one of the largest in the collections is 16 mm. long, 15 mm. wide, and 10 mm. thick. Shell finely punctate.

The teeth of the pedicle valve show no trace of any dental plates and the delthyrium is closed with deltidial plates. In the brachial interior the median septum is thin and low and extends forward for only about one-fifth of the length of the valve. The spires have not been observed.

Discussion.—*H. subgibbosa* is most similar to the Waldron species *H. evax* (Hall 1863A, p. 213) but differs in being more strongly biconvex. Also *H. evax* has a more prominent ventral sulcus.

Holotype.—USNM No. 115326.

Distribution.—This is a moderately common species in the Henryhouse formation; specimens from collections 1, 2, 3, 10, 11, 12, 15, 16, 18, 20. Type locality, 10.

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THE PALEONTOLOGY OF NORTHWESTERN VERMONT. I. NEW LATE CAMBRIAN TRILOBITES

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ABSTRACT—Trilobites from above the overthrust at Highgate Falls, Vermont, are described and assigned to 10 species (eight new) and nine genera (two new). The fauna has Ordovician affinities, but stratigraphic, structural, and paleontological evidence is presented to support a late Cambrian dating. A new formation name, the Morses Line slate, is proposed.

The classification of the Norwoodiidae and their relations to the Cryptolithidae are discussed. *Missisquoia*, n. gen., is regarded as the earliest phacopid trilobite.

INTRODUCTION

THE Trempealeauian rocks of the St. Albans area of northwestern Vermont are richly fossiliferous, but their faunas are not yet fully known. Raymond (1924, 1937) has described a large number of species from the middle part of the Gorge formation, and a fauna containing *Hungaia magnifica* (Billings), 1860, has been collected from the Milton dolomite facies of the Clarendon Springs dolomite, but it remains undescribed. The present paper describes the trilobites of a third fauna that is assigned to the uppermost part of the Gorge formation.

Nearly all of the specimens discussed in this paper were collected by Professor Cecil H. Kindle, of the College of the City of New York, who prepared the specimens and arranged for many of the photographs to be taken. Mr. George Sanderson and I have made small additional collections.

My thanks are due to Professors Percy E. Raymond and Marland P. Billings, of Harvard University, Robert R. Shrock, of the Massachusetts Institute of Technology, and Norman Denson and Preston E. Cloud, of the United States Geological Survey, for their suggestions and guidance, and to Professor Horace D. Thomas, of the University of Wyoming, for reading the completed manuscript.

All holotypes and figured specimens have been returned to Dr. Kindle for deposit in the United States National Museum. Representative selections of specimens have also been deposited in the Museum of Comparative Zoology and in Dr. Kindle's personal collection.

DISTRIBUTION

The zone containing the trilobites described herein has been found at only two places, both in the gorge of the Missisquoi River, at Highgate Falls, Vermont. The principal quarry was in thin-bedded limestones on the north wall of the gorge, about 20 feet above the point where the trace of the Highgate Falls overthrust reaches the floor. These limestones lie above a 10- to 15-foot bed of edgewise dolomite conglomerate and all are above the Highgate Falls overthrust, which is discussed below. The limestone beds are commonly 10 to 25 mm. thick and are separated by black shales less than 2 mm. thick. The limestone is gray-blue on weathered surfaces and gray to black where fresh. All exposures are sparingly fossiliferous but the most fossiliferous rocks seem to have been quarried away.

A second locality lies about 100 yards upstream from the bridge at Highgate Falls, on the north bank of the river, where the thick edgewise conglomerate dips down to the east, bringing the thin limestones down again in an argillaceous facies. This locality is exposed only at extremely dry periods, when the river is unusually low. The collection made here contained only brachiopods.

STRATIGRAPHY

It is beyond the scope of this paper to discuss at length the Upper Cambrian and Lower Ordovician stratigraphy of northwestern Vermont. This subject is covered in detail in a doctoral dissertation which it is hoped will be brought to publication in the near future.

The fauna from which the trilobites described below are taken lies above the Highgate Falls overthrust, which is a subsidiary thrust cutting the northern part of the Rosenberg thrust sheet (Clark, 1934, p. 8), which is one of a series of overthrust sheets lying along the east side of the Champlain Valley in northwestern and west-central Vermont. The Highgate Falls overthrust carries Upper Cambrian and Lower Ordovician rocks westward over rocks of similar age. At Highgate Falls the thrust is developed in calcareous slates of the Gorge formation, but to the north the sole of the thrust is formed by Lower Ordovician formations. Southward the fault seems to die out within the Upper Cambrian Hungerford slate.

The beds containing this new fauna appear to be conformable beneath the Lower Ordovician Highgate formation, but areal mapping has led me to the conclusion that a disconformity must exist between the fossiliferous zone and the Highgate.

It seems that at the end of Cambrian time the sea withdrew from the western part of the St. Albans area, and a monocline developed in the Gorge formation. The folding of the monocline formed a trough on the eastern side of the area, in which at least 2500 feet of calcareous slate, limestone, and intercalated limestone conglomerate were deposited. This formation is here named the Morses Line slate, after the town of Morses Line, which lies on the International Boundary, in the northwestern ninth of the Enosburg Falls quadrangle, Vermont.

The Morses Line Slate includes the Ordovician conglomerate previously known as the "Corliss breccia" (Schuchert, 1937, p. 1074; Raymond, 1937, p. 1140), which I now regard simply as a local lens in the Morses Line. The younger Highgate formation was formed when the trough filled and the sea again spread over the land to the west.

The rocks containing the trilobites described below lie stratigraphically below the Morses Line slate and were part of the uplifted area west of the monocline in the Gorge formation. It is because of the exposure during Morses Line time that these rocks are now overlain directly by the Highgate formation.

It seems most logical to place the boundary between the Ordovician and Cambrian systems below the Morses Line slate, and above the Gorge formation.

ORIGIN OF THE FOSSIL DEPOSIT

Reconstruction of the fossil deposit as it originally appeared in the rock is difficult because most of the specimens were separated as single blocks when the collection was received, but subsequent collections, although small, have yielded some evidence about the manner of formation.

As soon as a study of the brachiopods is completed, a numerical analysis of the composition of the fauna as a whole can be presented, but some data regarding the trilobites alone are available at this time.

As stated above, the fossils at the main quarry are in a sequence of alternating black to blue-black limestones, separated by very thin black shales. At the small outcrop upstream, the entire deposit is a black calcareous shale. The shale outcrop has yielded only brachiopods and will not be discussed further.

In the main quarry, the limestone beds have yielded virtually all of the specimens. The shales have yielded eight specimens of graptolites, and a single flattened trilobite, which is shown on plate 22, figure 16.

The fossils in the limestone are randomly oriented. In a few hand specimens of the limestone there is a slightly greater concentration of fossils near the top of the bed, but this is not common. The remarkable feature of the deposit is the concentration of cranidia, almost to the exclusion of other parts of the trilobite. For example, more than 50 cranidia of *Parabolinella triarthroides* are preserved, but only about a dozen pygidia were found. The only pygidia recovered in quantity are those of *Missisquoia typicalis* and *Symphysurina* (*Symphysuroides*) *minima*.

This selection seems to have been due to the difference in convexity of the various fragments of the test. Most of the cranidia, and the pygidia of *M. typicalis* and *S. minima*, are convex, whereas the scarcer pygidia, free cheeks, and thoracic segments are all more or less flat. The concentration of the convex, and presumably more easily transportable, fragments indicates that this deposit was formed by introduction of

additional convex forms rather than removal of the flatter specimens.

The fossils do not seem to have been carried far, however, for few are damaged or worn. Furthermore, the confinement of the trilobites to the limestones probably indicates an original environmental preference that has not been seriously disturbed.

It may be noted that the single trilobite preserved in shale retains the thorax, a free cheek, and the hypostoma, which suggests that the animal was a living individual, accidentally buried in mud.

The sea in which these beds were deposited seems to have been little subject to storm action, for the limestones, as far as they are exposed, are regularly and evenly bedded. The base of the section is marked by a thick edgewise conglomerate that probably represents the action of one or more severe storms, but the overlying beds are undisturbed. The regular incursions of mud may be storm-transported debris, but the limestones are not disturbed, and it is possible that the muds are the result of some cyclical change in sedimentation.

AGE OF THE FAUNA

This fauna shows a mingling of late Cambrian genera from the southern Appalachians and British Columbia with latest Cambrian and early Ordovician forms from Scandinavia, the Maritime Provinces of Canada, and South America.

The most prominent trilobites are the olenids, which are common in the late Cambrian and early Ordovician of Scandinavia, but the brachiopods and some of the trilobites show American affinities. It would be unwise to make a categorical statement regarding the age of this fauna, so the paleontological evidence, which indicates that the deposit is of latest Cambrian age is discussed in detail below. The structural evidence has been discussed above.

Graptolites

The presence of dendroid graptolites suggests at first glance that the rocks are of Ordovician age, but the demonstrated existence of Late Cambrian dendroids, plus the poor preservation of the specimens, renders their evidence equivocal. *Callograptus*, to which the specimens in the collection are provisionally assigned, is known to have late Cambrian representatives, and the dendroid *Dictyonema vermontensis* is reported from the Dresbachian Hungerford slate by Ruedemann (1947, p. 165), who calls the formation the "Russell slate."

Brachiopods

The brachiopods in the collection have not been fully studied, but *Syntrophina carinifera* Ulrich and Cooper, 1936 (pl. 23, figs. 19, 20), is a known species, useful in dating. *S. carinifera* is found in the "*Hungaia magnifica* zone" (Ulrich and Cooper, 1938, p. 20) which is present in situ, in the Milton dolomite facies of the Clarendon Springs dolomite, 20 miles south of the present locality. Although the fauna has not been described, a list of the species has led me to the conclusion that the fauna is correlative with the upper part of the Gorge formation, and may even be of late Trempealeau age.

Trilobites

Parabolinella.—This genus is characteristic of the Upper Cambrian and Lower Ordovician rocks in both Scandinavia and South America. The species *P. triarthroides* is assigned at its type locality to the *Triarthrus* fauna, which is correlated with the upper Tremadoc. In northern Argentina *Parabolinella* is found above the zone containing *Leiostegium* Raymond, 1913, but in the St. Albans area the relative positions are reversed, *Leiostegium* being abundant in the Highgate and younger formations. The evidence of this species is equivocal because of the geographic separation of the two localities from which it is known.

Plicatolina.—This genus has another representative in the lower Tremadocian rocks of Salitre, Bolivia (Harrington and Leanza, 1943, pp. 348–351), where it is associated with *Geragnostus* and *Gallagnostus* (= *Litagnostus* ?). As in the case of *Parabolinella triarthroides*, however, geographic separation makes impossible the use of this genus for dating.

Symphysurina (*Symphysuroides*).—This subgenus has commonly been assigned to the Ordovician. It was originally described by Raymond (1937, p. 1117) from pebbles in the Lower Ordovician "Corliss breccia," which is here regarded as a local conglomer-

ate lens in the Morses Line slate. *Symphysuroides* has representatives in several faunas in the North Atlantic region, and its presence favors an Ordovician age assignment.

Terranovella.—This genus was described from Upper Cambrian pebbles in the Cow Head breccia of Newfoundland.

Holcacephalus (*Hardyoides*).—This subgenus was described from the upper Franconian "*Taenicephalus* limestone" of British Columbia. Smooth Holcacephalinae range from the Franconian to the Lower Ordovician, however, and *H.* (*H.*) *glabrus* is here regarded as an intermediate stage of development; it provides little conclusive evidence for dating.

Pseudagnostus.—This genus has too long a range to provide unequivocal evidence for dating, but the principal development of the genus is in the middle and late Late Cambrian. *P. semiovalis* Kobayashi, 1937, from the early Tremadocian "*Kainella* zone" of South America, is the youngest representative. Considering the distribution in time and space of the species listed by Kobayashi (1939, pp. 157–158) the presence of the genus seems to favor a late Cambrian age for the fauna.

Homagnostus.—This genus is not known to range above the Upper Cambrian, and in central and western United States it is characteristic of the Dresbachian and lower Franconian rocks (Howell and others, 1944, pp. 994–995). In Scandinavia the genotype species is found in the *Olenus* and *Orusia* zones, and in England it is found in the *Lingula* flags. The effacement of the form here described suggests the possibility that the species is a straggler, but the genus indicates a Cambrian age more strongly than an Ordovician age.

Litagnostus.—This genus was not considered in dating the fauna because it is unwise to place reliance on smooth agnostids, due to the danger of confusing homoeomorphs.

Two homotaxial equivalents of this fauna are to be found at Salitre, Bolivia, and in the "*Olenus* beds" of Mt. Jubilee, British Columbia.

The Bolivian faunule (Harrington and Leanza, 1943) contains *Plicatolina*, *Geragnostus*, and a smooth agnostid assigned by Howell to *Gallagnostus* (= *Litagnostus* ?). This faunule is regarded by Harrington and Leanza as of Early Tremadocian age.

The "*Olenus* beds" (Kobayashi, 1938) contain two zones, an upper "*Parabolinella* limestone" containing *Parabolinella*, *Homagnostus*, and *Pseudagnostus*. The last genus is represented by *P. latus* Kobayashi, 1938, which differs very little from *P. araneavelatus*, described in this paper. Kobayashi regards the "*Olenus* beds" as of Franconian age.

SUMMARY

The evidence discussed above shows that the brachiopods and the trilobite subgenus *Symphysuroides* are known from northwestern Vermont. The brachiopod is unequivocally Cambrian, and the trilobite is known from pebbles in the lowest part of the Ordovician (the "Corliss breccia").

As the geographic separation from Ver-

EXPLANATION OF PLATE 21

Figures *1*, *2*, *4*, *6–8*, *10*, *11*, *13–17* from negatives made at the U. S. National Museum and supplied by Dr. Cecil H. Kindle.

FIGS. *1–8*—*Terranovella gelasinata* Shaw, n. sp. *1*, *2*, dorsal views of incomplete adult cranidia, X6; *3*, *4*, dorsal views of immature cranidia with inflated frontal limb, X6, X9; *5*, *7*, lateral and dorsal views of immature cranidium with inflated frontal limb, X6; *8*, same cranidium, X10; *6*, holotype cranidium, X3. (p. 104)

9–19—*Symphysurina* (*Symphysuroides*) *minima* Shaw, n. sp. *9*, dorsal view of cranidium 2.3 mm. long, showing fully preserved pointed palpebral lobe, X8; *10*, *11*, dorsal and lateral views of holotype cranidium 9.3 mm. long, X2; *12*, posterior oblique view of fully exfoliated cranidium 10.7 mm. long preserving complete strap-like posterior limb and showing traces of dorsal furrows, X2; *13*, pygidium 2.3 mm. long, X6; *14*, *15*, two largest pygidia 3.6 mm. and 4.3 mm. long, X2; *16*, exfoliated pygidium probably belonging to this species, X6, X3; *19*, free cheek, X2; *17*, assigned hypostoma, X6. (p. 107)

18—*Geragnostus* (*Micragnostus*) *bisectus* (Matthew), 1892. Pygidium with long narrow rhachis. Compare plate 23, figure 18. X3. (p. 111)

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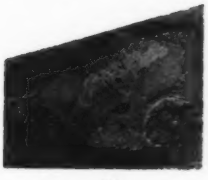

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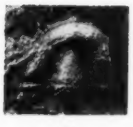

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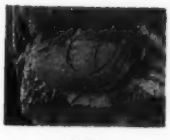

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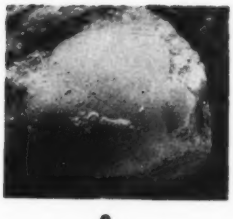

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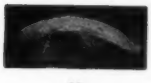

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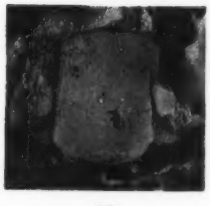

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Shaw, Vermont late Cambrian trilobites

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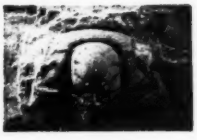

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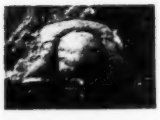

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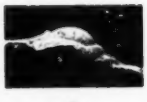

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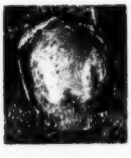

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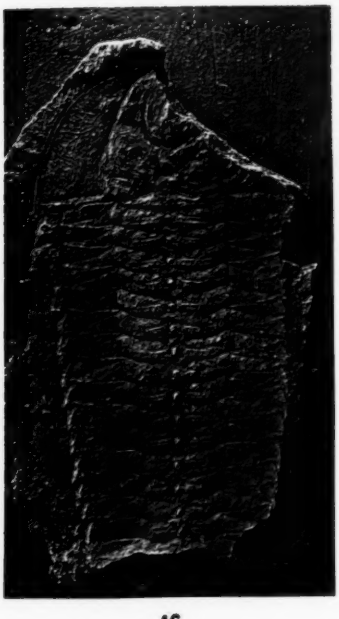

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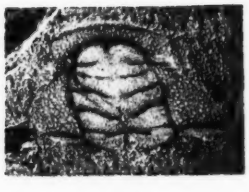

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Shaw, Vermont late Cambrian trilobites

mont increases, the indicated age diverges from the latest Trempealeauian in about equal amounts above and below. Going north and east through the North Atlantic region we find *Geragnostus bisectus* in the lowest Ordovician of New Brunswick, *Terranovella* in the Upper Cambrian of Newfoundland, *Symphysuroides* in the Lower Ordovician of Greenland, and *Parabolinella* in the Lower Ordovician of Scandinavia. *Homagnostus* is found in the Upper Cambrian of Scandinavia and England.

Westward, in the Cordilleran region, the genera *Parabolinella*, *Holcacephalus* (*Hardyoides*), *Pseudagnostus*, and *Homagnostus* are all found in beds older than those in Vermont. Likewise, in the southern Appalachians *Homagnostus* is found in the lower Upper Cambrian rocks.

Finally, the genera and species found farthest from Vermont, in South America, show the greatest stratigraphic displacement. The genera *Plicatolina* and *Geragnostus* are found in the early Tremadocian of Salitre, Bolivia, and *Parabolinella triarthroides* is assigned at its type locality to the upper Tremadocian of Argentina.

Thus, if the evidence for dating be weighted according to geographic separation as well as stratigraphic position, it seems most probable to me that the beds are of latest Cambrian age and assignable to the Gorge formation.

The mixture of forms from the east and west suggests strongly that the barrier that arose in early Cambrian time and separated the Appalachian and Caledonian geosynclines during most of the early and Middle Cambrian had broken down by the time these beds were deposited. The paleontologic succession in northwestern Vermont shows a progressive mingling of Atlantic and Cordilleran forms with those of the Applachian area, from the end of the Middle Cambrian to the early Ordovician.

SYSTEMATIC PALEONTOLOGY

Subclass TRILOBITA Knorr and Walch, 1771
Order OPISTHOPARIA Beecher, 1897
Suborder PTYCHOPARIIDA Richter, 1933
Superfamily ELLIPSOCEPHALIDEA Richter, 1933
Family OLENIDAE Burmeister, 1843
Genus PARABOLINELLA Brögger, 1882

Olenus (*Parabolinella*) BRÖGGER, 1882, "Die silurischen Etagen 2 und 3 im Kristianiagebiet und auf Eker," p. 102, Kristiania (Oslo), Norway.

Parabolinella LAKE, 1908, Monograph of British Cambrian Trilobites, pt. 3, p. 63, Paleontogr. Soc.

Genotype.—Olenus (*Parabolinella*) *limitis* Brögger, 1882.

EXPLANATION OF PLATE 22

Figures *5–10*, *13*, *17–19* from negatives made at the U. S. National Museum and supplied by Dr. Cecil H. Kindle. All figures except *5* numbered in order of size, within each species.

FIGS. *1–10—Parabolinella triarthroides* Harrington, 1938. *1*, small cranidium, glabella including occipital lobe 1.09 mm. long, ×6½; *2*, *3*, dorsal and lateral views of cranidium 1.74 mm. long, ×5; *4*, cranidium 2.03 mm. long, ×5; *5*, cranidium 8.18 mm. long with rounded glabella, ×2; *6*, cranidium 3.55 mm. long, ×4; *7*, cranidium 5.22 mm. long, ×4; *8*, cranidium 7.24 mm. long, ×2; *9*, second largest cranidium, 13.92 mm. long, ×1½; *10*, pygidium assigned to species, 8.12 mm. maximum width, ×2. (p. 102)

10—Pseudagnostus bilobus Shaw, n. sp. Dorsal view of pygidium 2.19 mm. long showing lateral spine, ×2. (p. 112)

11–17—Plicatolina kindlei, n. gen., n. sp. *11*, dorsal view of smallest specimen found. Glabella 1.23 mm. long, with anterior glabellar furrow faint medially, rear three furrows complete, ×10; *12*, cranidium with first furrow obsolete medially, second furrow faint, last two complete, ×6; *13*, cranidium with first two furrows obsolete, third faint, last complete, ×6; *14*, cranidium with 3.89 mm. glabella, showing all four furrows obsolete medially, ×5; *15*, cranidium with 4.67 mm. glabella, all furrows obsolete medially, ×4; *16*, flattened shale specimen, holotype of species, thorax 38.5 mm. long, glabella probably about 15 mm. long, ×1. (p. 103)

18—Pygidium No. 1. With external impression of cranidium of *Holcacephalus* (*Hardyoides*) *glabrus*, ×9. (p. 114)

19—Pygidium No. 2. Posterior oblique view, ×9. (p. 114)

Parabolinella includes Olenidae having genal spines continuous with the borders of the free cheeks, the facial sutures commonly divergent before the eyes, a well developed anterior limb, and a pygidium that is unspined or bears a single pair of anterior spines.

The genus is here regarded as having the limits of variability set by Lake. Variability is particularly noticeable in the anterior limb, which is short in the genotype, *P. limitis* (Brögger), 1882, but long in *P. williamsoni* (Belt), 1868.

P. triarthroides, described below, is of the long-brimmed type. It may be that the structure of the anterior limb is of generic or subgeneric importance, but there is not sufficient material at hand to justify any separation here.

PARABOLINELLA TRIARTHROIDES
Harrington, 1938
Plate 22, figures 1–10

Parabolinella triarthroides HARRINGTON, 1938, Revista del Museo de la Plata, n. ser., Sec. Paleont., vol. 1, no. 4, p. 194, pl. 7, figs. 10, 11, text fig. 9.

Diagnosis.—*P. triarthroides* is characterized by a nearly square or slightly conical glabella, bearing two pairs of furrows, the posterior pairs being sigmoidal. Neither pair is continuous across the glabella.

Description.—Glabella either rectangular or tapering; either rounded in front or truncate. Two pairs of glabellar furrows, in most specimens obsolete adjacent to dorsal furrow. Anterior furrow perpendicular to dorsal furrow distally but curving gently rearward proximally; posterior furrows show sigmoid course typical of many Olenidae; neither pair continuous across center of glabella. Occipital ring, bearing low median node, well defined by uninterrupted occipital furrow. Center of eyes opposite first glabellar furrow and slightly behind midlength of cranidium. Eyes distant from glabella by one-third glabellar width. Ocular ridges strong, rising from pair of poorly defined anterior pits. Facial sutures run backward and inward, or rarely straight back from rim to eye; thence straight backward and outward, forming narrow, triangular posterior limb about three-fourths as wide as occipital ring. Anterior limb about one-third as long as glabella. Narrow rim separated from brim by marginal furrow containing small pits.

No free cheeks believed assignable to this species have been recovered.

Thorax unknown.

Pygidium assigned to species transverse; axial lobe conical, occupying about one-quarter of pygidial width; broadly rounded posteriorly, does not cross rim. Axial lobe marked by three distinct transverse grooves and less commonly by a fourth posterior groove, appearing as a pair of shallow pits partially dividing posterior segment. Three interpleural grooves, obsolescent distally. Pleural furrows run from proximal posterior corner of pleuron to distal anterior corner; well marked. Rim present; no marginal furrow; rim narrow and slightly arched immediately behind axial lobe. Anterior corners of pygidium bear facets.

Surface of test smooth.

Remarks.—*P. triarthroides* most closely resembles *P. triarthra* (Callaway), 1877, *P. williamsoni* (Belt), 1868, and *P. punctolineata* Kobayashi, 1936. *P. triarthra* is readily distinguished by the presence of three pairs of glabellar furrows of which the anterior pair is divided into two parts. *P. williamsoni* differs in the inward course of the facial sutures immediately behind the eyes and in having the rear pair of furrows continuous across the glabella. *P. punctolineata* has straight glabellar furrows instead of the sigmoid rear pair found in *P. triarthroides*. Straight rear furrows also serve to distinguish *P. incerta* (Rasetti), 1945, from *P. triarthroides;* however, there does not seem to be any notable difference between *P. punctolineata* and *P. incerta*, and it may be that these two are synonymous.

Many workers will doubtless be tempted to recognize the Vermont and Argentine trilobites as separate species because they are widely separated geographically and because they lie on opposite sides of the Cambro-Ordovician systemic boundary. E. S. Richardson, Jr. (1948, p. 369) and N. D. Newell (1949) and I (1950, pp. 110–111) have expressed two points of view on this subject.

There is the possibility that the trilobites from these two widely separated localities may be homoeomorphs, but the qualitative

similarity of the Vermont specimens to Harrington's description is supported by a quantitative analysis, which reveals that no significant statistical differences exist between the two. The statistical study will be presented at another time.

Inasmuch as the North and South American specimens are not separable on either qualitative or quantitative grounds, they are here regarded as a single species.

Genus PLICATOLINA Shaw, new genus

Genotype.—*Plicatolina kindlei* Shaw, new species.

This genus is proposed to include two species of olenid of the *Parabolina* type, *Parabolina pheidolopyge* Harrington, 1938, and *Plicatolina kindlei* Shaw, n. sp., described below.

These trilobites resemble both *Parabolina* and *Parabolinella* but differ from both in having four pairs of glabellar furrows in addition to the occipital furrow. The furrows tend to become obsolescent as the trilobite increases in size.

Parabolinella rugosa (Brögger), 1882, may possibly belong to this genus also.

Plicatolina pheidolopyge was erected upon a pygidium, but Harrington and Leanza (1943, pp. 349–350, pl. 2, figs. 9–10) have assigned a cranidium to the species. The reference of the species to *Plicatolina* is based on the cranidium, and if the cranidium and pygidium should prove not to represent the same species, the cranidium should remain in *Plicatolina*.

PLICATOLINA KINDLEI Shaw, n. sp.
Plate 22 figures 11–17

Diagnosis.—This species differs from *P. pheidolopyge* in its tuberculate surface.

Description.—Species known from 18 young cranidia and a single flattened adult (pl. 22, fig. 16). Glabella elongate, occupying most of the cephalic length. Four glabellar furrows, all slightly curved toward the rear; in smallest specimen (1½ mm. long) anterior pair obsolescent in center, remainder extending across glabella. In specimens of larger size, furrows become shallow and finally obsolete medially until in the largest isolated cranidium (5 mm. long), first three furrows are entirely separated, and only posterior furrow retains faint connections across glabella. Anterior end of glabella indented by short, shallow median furrow.

Occipital ring marked by groove that originates in front of occipital node and runs diagonally backward to cut rear margin of ring at point midway between center line of cranidium and dorsal furrow.

Anterior limb short, from one-eighth to one-tenth as long as glabella. Tuberculation faintly developed on brim in small specimens, but in largest cranidia brim is smooth. Three or four specimens appear to have longitudinal striations across brim and widely spaced shallow pits in marginal furrow. Rim narrow and convex.

Palpebral lobes lie close to glabella, connected with glabella by prominent ocular ridges arising opposite anterior glabellar furrow and running straight out to eyes. Palpebral lobes damaged in most specimens but seem to have been prominent and short.

Fixed cheeks and posterior limbs tuberculate. Tubercles weakly developed on larger cranidia, but posterior limbs are never smooth. Posterior limbs triangular, marked by marginal furrow that meets center of occipital ring.

A single specimen retaining a free cheek and part of the thorax was found in the shales between the limestones (pl. 22, fig. 16). This specimen is completely flat so that some distortion exists, but it shows that the genal spine was short, reaching only to the front of the fourth thoracic segment. The free cheek is marked by an anastamosing veinlike network similar to that which radiates from the eyes of many of the Olenidae. The glabella shows only two or three pairs of furrows, but because of the crushing, no exact description of them can be given. The anterior part of the glabella bears an oval-shaped mark that is probably the impression of the hypostoma on the dorsal side of the test. There are 16 thoracic segments, each of which bears a median node. The slight taper of the axial lobe indicates that either the thorax was long, or the axial lobe of the pygidium was very broad, much as in the pygidium assigned to *Parabolinella triarthroides*. However, the course of the pleural grooves makes it impossible that the pygidium assigned to *P. triarthroides* could belong to *Plicatolina kindlei*. In *P. kindlei* the grooves run from the anterior proximal

corner of the pleuron to the posterior distal corner; in the pygidium assigned to *Parabolinella triarthroides* this course is reversed.

The hypostoma is assigned to this species because of the similarity of its outline to the impression on the glabella of the flattened specimen; however, it may belong to *P. triarthroides*. There is no certainty on this point at present. The body of the hypostoma is convex and marked by two low protuberances. There is a thin lateral rim which disappears posteriorly.

Remarks.—This species is similar in the advanced position of the eyes and the manifold lobation of the glabella to the immature forms of some other olenids, e.g., *Parabolinella evansi* Kobayashi, 1935 (see Kobayashi, 1938, p. 186, pl. 16, fig. 14).

Plicatolina kindlei resembles some species of *Parabolina*, and a similarity to *Parabolinella* is shown by the course of the facial sutures, which are divergent in front of the eyes, and by the advanced position of the eyes.

The cranidium of *P. kindlei* resembles that of *Parabolinella limitis* in the length of the brim, shape of the posterior limbs and general outline. *P. ? rugosa* (Brögger), 1882, has as many glabellar furrows as *P. kindlei* but differs in most other respects.

Family PTYCHOPARIIDAE Matthew, 1888 (?)

Genus TERRANOVELLA Lochman, 1938

Terranovella LOCHMAN, 1938, Jour. Paleontology, vol. 12, no. 5, p. 473.

Genotype.—*Terranovella obscura* Lochman, 1938.

This species and genus were described by Lochman from what appear to be, in the light of the specimens here described, immature forms. The gibbous frontal limb of the immature cranidium gives way in the adult to a slightly convex brim and other features typical of the Ptychopariidae. However, inasmuch as it is unusual to find a gibbous brim in the Ptychopariidae at any growth stage, it is possible that this genus may have some affinities with the Solenopleuridae.

The adult cephalon closely resembles that of *Proaulacopleura* Kobayashi, 1936, so that it is unfortunate that the young stages of that genus are not known so that they might be compared with *Terranovella*.

Lochman's generic description may be emended somewhat as follows: Cranidium of normal ptychopariid type in adult, with quadrate or elongate-conical glabella. Two or three pairs of glabellar furrows; anterior pair reduced. Occipital ring well-marked; may or may not be spined. Fixed cheeks of medium width; small palpebral lobes. Brim very convex in young specimens; of reduced convexity and greater length and width in adults.

Free cheek rimmed and produced into a genal spine twice as long as cranidium.

TERRANOVELLA GELASINATA Shaw, n. sp.

Plate 21, figures 1–8; Plate 24, figures 9–11

Diagnosis.—The young of this species differ from the genotype, *T. obscura*, in having three glabellar furrows, in lacking an occipital spine, and in having a smooth instead of a granulated surface.

The adult, which is closest to *Proaulacopleura buttsi*, differs from that species in having one more glabellar furrow, and a sinuous rather than a straight occipital furrow.

Description.—This species is known from two dozen cranidia and half a dozen free cheeks. The cranidium shows a change during its growth, principally in the shape of the brim and the glabella.

Large cranidia have a conical glabella, truncate or somewhat rounded in front. Glabella marked by two straight, obliquely oriented furrows and a pair of anterior notches representing a third set of furrows. Occipital ring well defined, bearing a median node. Strong ocular ridges arise from a deep dorsal furrow opposite anterior glabellar notch and curve slightly rearward to palpebral lobes, which rise nearly or quite to level of glabella. Center of palpebral lobes lies approximately opposite first of two well defined pairs of glabellar furrows, slightly behind midlength of cranidium.

Brim tumid, about one-third as long as glabella, marked by obscure radiating ridges which on some specimens are crossed by faint inosculating transverse ridges; the latter may be impressions from the ventral surface, however. Rim prominent, rounded,

and arched transversely; separated from brim by deep marginal furrow which appears in some specimens to be faintly pitted.

Facial sutures widely divergent in front of eyes; turned downward at anterior ends because of transverse arching of brim. Sutures turn abruptly outward behind eyes to form sharply pointed, triangular posterior limbs approximately equal in width to transverse width of occipital ring.

Free cheeks bear slender genal spines about twice as long as cranidium. Cheeks rimmed, arched anteriorly.

Small individuals differ from large ones in the structure of the brim and in the proportions of the glabella. In small cephala the width of the occipital ring is commonly less than half the length of the glabella, but in the large specimens the proportion increases by shortening of the glabella to 0.7 or more. Thus, the younger heads have a relatively longer glabella than the older ones.

More striking, however, is the change in the shape of the brim. In small cranidia the central portion of the brim is inflated to a point level with or above the glabella, and the rim is strongly depressed (pl. 21, figs. 3–5, 7, 8). The facial sutures are horizontal in front of the eyes for a short distance and then plunge vertically downward to the rim. As the cranidium increases in size the brim is flattened by the upward movement of the rim so that the brim of the larger cranidia, although remaining convex, no longer has the gibbous form of the young. A comparison of end members of the series would suggest that two species are present, but a complete series of specimens connects them.

Superfamily CRYPTOLITHIDEA Richter, 1933
Family NORWOODIIDAE Walcott, 1916

Norwoodidae WALCOTT, 1916, Smithsonian Misc. Colls., vol. 64, no. 3, p. 168.

This family includes several genera of minute proparian trilobites characterized by a convex cephalon, surmounted by a well defined conical or cylindrical glabella. The eyes lie near the front of the glabella, at or in front of the midlength of the cephalon. Genal spines present. The anterior limb is nearly as long as the glabella and in most species is deflected abruptly downward. The thorax has five to nine segments. The pygidium is transverse and subequal to, to one-half as wide as, the cephalon.

It seems that the forms now included in this family can be separated into two distinct groups of genera, which are here designated as the subfamilies Norwoodiinae and Holcacephalinae.

The Norwoodiidae have heretofore been included in the order Proparia Beecher, 1897, but they are here referred to the Opisthoparia because of the assumed relationship between the Holcacephalinae and the Cryptolithidae, which is discussed below. The relationship of the Norwoodiidae to the Raphiophoridae and Shumardiidae, both of which have been included by most authors in the Cryptolithidea, has not been determined.

Subfamily NORWOODIINAE Shaw, new subfamily

This subfamily is proposed to include those Norwoodiidae with eyes set close to the glabella, deeply cutting facial sutures, and large free cheeks. The glabella is conical, with well-marked furrows in some species; it commonly bears an occipital spine. The brim is ordinarily long, and the genal spines are long and curved. *Norwoodia* Walcott, 1916, and *Norwoodella* Resser, 1938, are included in the subfamily.

Subfamily HOLCACEPHALINAE Shaw, new subfamily

In the Holcacephalinae are included those Norwoodiidae characterized by a highly convex, cylindrical glabella, commonly lacking both glabellar furrows and an occipital spine. Eyes are at or in advance of the midlength of the cephalon and are so far from the glabella that the free cheeks are reduced to small triangular plates. Genal spines are ordinarily present but are stout and not so long as in the Norwoodiinae. The Holcacephalinae include *Paranorwoodia* Rasetti, 1945, and *Holcacephalus* Resser, 1938, with the subgenera *Holcacephalus*, s.s., *Hardyoides* Kobayashi, 1938, and *Levisaspis* Rasetti, 1943.

Levisaspis is of especial interest because it is the youngest member of the Holcacephalinae. In *Levisaspis* smoothing has

progressed further than in *Hardyoides* and *Holcacephalus*. *Paranorwoodia* seems to be a specialized form in which all features have been effaced and the eyes have migrated toward the cephalic margin.

Students of the Cryptolithidae believe that the ancestral stock from which the family must have been derived was a small, isopygous form, with few thoracic segments. In these respects the Norwoodiidae are admirably suited, and the Ordovician *Levisaspis* shows a reduction in the number of thoracic segments from the eight or nine of the Cambrian forms, to five. In addition there is a striking similarity between the young stages of the Holcacephalinae and those of the Cryptolithidae, a resemblance that is also carried into some of the adult forms.

It is not held here that the Holcacephalinae were the direct ancestors of the Cryptolithidae, but rather that the Holcacephalinae seem well adapted to have given rise to another group of trilobites that were themselves the direct ancestors.

Holcacephalus s.s.	*Hardyoides*	*Levisaspis*
1. *Surface granulate*	1. Smooth	1. Smooth
2. Ocular ridges	2. *No ridges*	2. Ocular ridges
3. Rim present	3. Rim present	3. *Rim absent*
4. Thorax with 8 or 9 segments	4. Thorax not known	4. Thorax with 5 segments

Genus HOLCACEPHALUS Resser, 1938

Holcacephalus RESSER, 1938, Geol. Soc. America Special Paper 15, p. 81.

Subgenus HARDYOIDES Kobayashi, 1938

Hardyoides KOBAYASHI, 1938, Japanese Jour. Geol. Geogr., vol. 15, nos. 3–4, p. 177.

Subgenotype.—*Hardyoides minor* Kobayashi, 1938.

Minute trilobites with highly convex semicircular cephalon.

Glabella narrow, cylindrical, and nearly or quite unmarked except for the distinct occipital furrow. Brim and posterior limbs smooth, turned sharply downward at the edges and set off all around by a marginal furrow. Rim extended into genal spines. Facial sutures proparian, with the anterior branch running almost directly forward and the posterior branch almost directly to the side from the palpebral lobes. Palpebral lobes small, knob-like, opposite the anterior end of the glabella, midway between the glabella and the outer edge of the cephalon. Ocular ridges absent. Surface smooth.

Comparisons.—All three of the subgenera of *Holcacephalus* are very much alike in general appearance, and the differences that separate them, while easily recognizable, are of such a minor nature that they are here regarded as of subgeneric importance. The attributes of each subgenus of *Holcacephalus* are tabulated below; the distinctive features are italicized.

HOLCACEPHALUS (HARDYOIDES) GLABRUS Shaw, n. sp.

Plate 24, figures 1–5

Description.—Glabella subclavate and entirely smooth on outer surfaces; one exfoliated specimen shows faint traces of two pairs of glabellar furrows. Rim present but varies in prominence, being conspicuous in some specimens and greatly reduced in others. The rim commonly breaks away in preparation, but the species seems never to be genuinely rimless.

Two small transverse pygidia are assigned to this species because of their similarity to pygidia of *Holcacephalus* (*Holcacephalus*) *tenerus* (Walcott), 1916. Pygidia semi-elliptical, with prominent rim of even width, set off by deep marginal furrow. Axial lobe is narrow and crossed by four distinct grooves, which continue across pleural lobes to margin. Pleural furrows close to, and parallel with, interpleural grooves, giving appearance of unusually wide grooves.

Comparison with Holcacephalus (Hardyoides) minor.—*H. glabrus* has longer genal spines than the subgenotype, it lacks the glabellar furrows found in *H. minor*, and the glabella of *H. glabrus* is subclavate instead of slightly tapered as in *H. minor*. There is a median node on the occipital ring of all specimens of *H. glabrus*, but none is visible on Kobayashi's photograph nor is one indicated in his drawing of the holotype.

Suborder REDLICHIIDA
Richter, 1933
Superfamily DIKELOCEPHALIDEA
Richter, 1933
Family ASAPHIDAE
Burmeister, 1843
Genus SYMPHYSURINA Ulrich
in Walcott, 1924
Subgenus SYMPHYSUROIDES
Raymond, 1937

Symphysuroides RAYMOND, 1937, Geol. Soc. America Bull., vol. 48, no. 8, p. 1117.

Symphysuroides was erected by Raymond as a genus to include:

"Asaphidae with short smooth brimless shield, ill defined dorsal furrows, and without pygidial spine." *Symphysuroides latus* Raymond, 1937, was chosen to be the genotype.

The new species described below agrees in all details with *Symphysuroides*, and in addition, the cranidium, free cheek, and hypostoma have also been recovered. The similarity of these parts to those of other species of *Symphysurina* leads me to regard the separation on the basis of pygidia alone as of no more than subgeneric value.

SYMPHYSURINA (SYMPHYSUROIDES)
MINIMA Shaw, n. sp.
Plate 21, figures 9–19

Diagnosis.—The pygidium of this species is similar in most respects to that of the subgenotype except that it is smaller and shows two faint lateral grooves on the axial lobes, whereas the holotype pygidium of *S. lata* is entirely smooth. Since the cranidium of *S. lata* is not known, no comparison with *S. minima* is possible.

Description.—Cephalon transversely semielliptical. Cranidium smooth, shows no trace of glabella except on exfoliated specimens, in which dorsal furrows are visible behind the palpebral lobes. At crest of cranidium, on center line of palpebral lobes, is a small, prominent median tubercle. Rear of cranidium overhanging. Posterior limbs, preserved in only one specimen (pl. 21, fig. 12), are long and strap-like; commonly they are broken off and appear square. Palpebral lobes rounded or with an obtusely angular outer edge. Brim quadrate, marked by low, narrow, flat-topped rim.

Free cheek smooth, bearing short genal spine; similar to cheek assigned to *S. woosteri* except for absence of crenulated doublure. There appears to have been no rostrum, the doublure extending under the cranidium and meeting in a single median suture.

Pygidium transverse, semioval, and smooth, except for poorly defined axial lobe, which bears two faint grooves, obsolete medially. Four faint furrows appear on the axial lobe in some exfoliated specimens and faint grooves appear on anterior portions of pleural lobes (pl. 21, fig. 16). Axial lobe bluntly rounded and falls short of rear margin by one-fifth of pygidial length. Doublure wide, marked by irregular transverse striations. Facets on anterior angles.

The hypostoma assigned to this species is close to Ulrich's generic description (Walcott, 1924, p. 108) in being alate anteriorly, with anterior edge pitted medially, making the whole appear bilobed. Body of hypostoma inflated; posterior to body is transverse elevation bearing small node on either end. Deep lateral and posterior marginal furrow. Less than half a dozen specimens were found, but these show that the hypostoma is variable in relative length and width; one specimen is almost round, save for the anterior lobes, whereas the more common type is elongate (pl. 21, fig. 17).

Comparison with other species.—*S. minima* is much like *S. angustata* (Sars and Boeck), but the latter differs in having blunt posterior limbs, a more abrupt downward deflection of the front of the cranidium, and in lacking all trace of the axial lobe of the pygidium on the exterior of the test. The only significant difference between *S. minima* and *S. elegans* Poulsen, 1937, is the absence of genal spines in the latter.

Superfamily PHACOPIDEA
Richter, 1933

Phacopidea RICHTER, 1933, "Crustacea" in Handwörterbuch der Naturwissenschaften, 2d ed., vol. 2, p. 852, Jena.
Phacopidacea DELO, 1935, Jour. Paleontology, vol. 9, no. 5, p. 404.

Delo defines the superfamily as including: "Proparia with schizochroal eyes, large free cheeks, and 11 thoracic segments."

Family PHACOPIDAE Hawle and Corda, 1847 emend. Delo, 1935

Phacopides HAWLE and CORDA, 1847, "Prodrom einer Monographie der böhmischen Trilobiten," p. 65, Prague.
Phacopidae DELO, 1935, Jour. Paleontology, vol. 9, no. 5, p. 404.

Delo defines the family as including: "[Phacopidea] with reduced or obsolete glabellar furrows, compact body form, and in most a small rounded pygidium." To this might be added the qualification that in most genera the glabella extends to the rim.

Subfamily ACASTINAE Delo, 1935

Acastinae DELO, 1935, Jour. Paleontology, vol. 9, no. 5, p. 405.

Delo's definition of the subfamily is: "Small, compact Phacopidae in which the anterior glabellar furrows are lightly impressed, the third pair usually deeper; eyes in most species small; pygidium small, rounded, mucronate in some species."

Missisquoia is included in this subfamily with some hesitation, but inasmuch as it agrees in all respects with Delo's diagnosis, and since the Acastinae include the oldest Phacopidae, it seems most logical to place the genus here.

Genus MISSISQUOIA Shaw, new genus

Genotype.—*Missisquoia typicalis* Shaw, new species.

Missisquoia includes Acastinae (?) in which the glabella is slightly tapered, and in which the facial sutures cut the lateral margin of the cephalon almost directly at the genal angles. There are no genal spines.

MISSISQUOIA TYPICALIS Shaw, n. sp. Plate 23, figures 1–10

Description.—Entire test known from two immature specimens, the smaller of which is shown on plate 23, figure 2. Test compactly formed; it is difficult to distinguish line of juncture between thorax and pygidium. Outline of entire test elliptical.

Cephalon semioval, slightly produced anteriorly. Glabella rectangular in smallest cranidium (0.55 mm.), but tapering glabella is characteristic of larger cranidia. Anterior glabellar notch is present in all specimens with glabellar length exceeding 1.76 mm., but is not present in smallest cranidia. Two pairs of glabellar furrows present as deep lateral notches; third anterior pair faintly impressed on side of glabella in front of eyes. Several specimens show faint traces of a fourth, anterior pair. Posterior furrows deflected rearward. Occipital ring well defined by deep occipital furrow. Eyes at center of head, strongly curved, and distant from the glabella by about one-half the glabellar width. Palpebral lobes prominent; commonly appear elevated because of flattening of specimen. No ocular ridges. Facial sutures run straight back from rim

EXPLANATION OF PLATE 23

Figures *2, 3, 5, 6, 8, 9, 11, 13, 15–17, 19, 20* from negatives made at the U. S. National Museum and supplied by Dr. Cecil H. Kindle. All figures numbered in order according to size.

FIGS. *1–10*—*Missisquoia typicalis* Shaw, n. gen., n. sp. *1*, meraspid cephalon, the smallest specimen found, ×12; *2*, complete but abraded meraspid, with four (?) thoracic segments and smooth pygidial margin, ×10; *3*, holotype cranidium, a young holaspid (?), ×9; *4*, fragmentary cranidium retaining full convexity, ×5; *5, 6*, large cranidia that have been crushed, turning up frontal limb and making glabella taper, ×6, ×9; *7*, two largest cranidia found and fragmentary pygidium ×3; *8*, pygidium with marginal spines but lacking terminal spike, ×9; *9*, smallest pygidium with marginal spines and terminal spike, ×9; *10*, pygidium with both spines and spike, ×5.

11—*Geragnostus* (*Micragnostus*) *bisectus* (Matthew), 1892, var. *brevis* Shaw, n. var. Type cephalon, ×6. (p. 112)

12–13—*G.* (*M.*) *bisectus* (Matthew), 1892, var. *typica* Shaw, n. var. *12*, second smallest cephalon, ×9; *13*, largest cephalon, ×6. (p. 111)

14–18—*G.* (*M.*) *bisectus* (Matthew), 1892. *14*, lateral view of pygidium with bulbous rhachis, ×8; *15*, pygidium with most bulbous rhachis, ×9; *16, 17*, pygidia with blunt or intermediate rhachis form, ×9; *19*, pygidium with pointed rhachis (Compare plate 21, fig. 18), ×5. (p. 111)

19–20—*Syntrophina carinifera* Ulrich and Cooper, 1936, *18*, dorsal exterior, ×2; *20*, exfoliated ventral, ×2. (p. 99)

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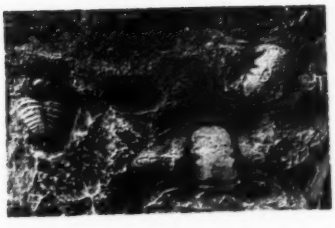

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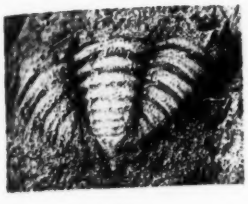

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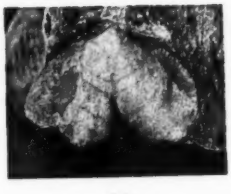

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Shaw, Vermont late Cambrian trilobites

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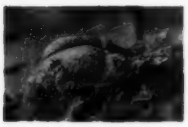
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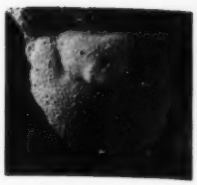
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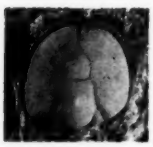
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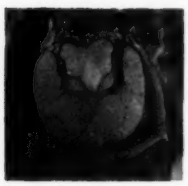
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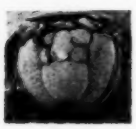
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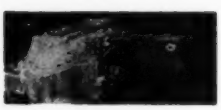
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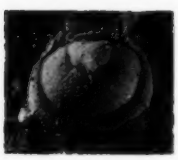
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Shaw, Vermont late Cambrian trilobites

to eyes, around palpebral lobes, thence straight to genal angle. The species is proparian, but poor preservation of the fine points of the genal angles, combined with the fact that the facial suture exists almost directly at the genal angle, makes determination of the fact difficult or impossible on most specimens.

A narrow rim is set off by a marginal furrow, but flattening of the cranidium gives most specimens the appearance of having a very deep marginal furrow and an upturned rim. This distortion may be seen on the specimen on plate 23, figure 5.

Free cheek small, convex, stands steeply inclined downward from the eyes. Surface of cranidium finely tuberculate.

The pygidium of this species shows a notable change during ontogeny. In immature specimens the pygidial margin is smooth, but larger specimens bear marginal spines and develop a short terminal spike, such as is common among many dalmanitids. It is interesting to note that the cephalon shows closest resemblance to the phacopids in its smallest growth stages, whereas the pygidium becomes more phacopid in larger specimens.

Small pygidia have a smooth margin and conical axial lobe, bearing no more than six rings. Pleural lobes marked equally by pleural grooves and interpleural furrows. Pygidia about 2.1 mm. long develop marginal spines which seem to be formed by distal splitting of the pleura. One pygidium, attached to an incomplete thorax has only the first two pleural segments extended into spines, indicating that the development of spines proceeded from front to rear. Median terminal spikes first are found on specimens 2.8 mm. long. Pygidium smooth, in contrast with tuberculate cranidium.

Note on the descriptive terminology of proparian trilobites.—The three ordinal names proposed by Beecher have long been modified for use as descriptive adjectives. Thus we speak of proparian, opisthoparian, and hypoparian trilobites, without implying reference to Beecher's classification. However, there are some trilobites, commonly referred to the Proparia, which the adjective "proparian" does not adequately describe. In these, the facial sutures exit directly at the genal angles or, in some species, vary slightly in position so as to produce some proparian and some opisthoparian individuals. For these intermediate trilobites I suggest the new term *amphiparian. Missisquoia typicalis* would be an example of an amphiparian trilobite and there are many among the Calymenidae.

Order AGNOSTIDA Kobayashi, 1935
Superfamily AGNOSTIDEA Richter, 1933
Family AGNOSTIDAE M'Coy, 1849

Agnostinae M'Coy, 1849, Ann. Mag. Nat. History, 2d. ser., vol. 4, no. 24, p. 402.
Agnostidae KOBAYASHI, 1939, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 5, pt. 5, pp. 144–145.

Kobayashi's diagnosis of the family: "Agnostidae with rounded, or less commonly subquadrate, shields; glabella not

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EXPLANATION OF PLATE 24

Figures *2*, *5–8*, *12*, *14*, *15*, *17*, *18*, *20*, *21* from negatives made at the U. S. National Museum and supplied by Dr. Cecil H. Kindle.

FIGS. *1–5*—*Holcacephalus* (*Hardyoides*) *glabrus* Shaw, n. sp. *1*, lateral view of holotype, ×8; *2*, dorsal view of cranidium, ×9; *3*, dorsal view of largest cephalon found, retaining free cheek, ×5; *4*, *5*, pygidia, ×10, ×9. (p. 106)

6—*Litagnostus raymondi* Shaw, n. sp. ×9. (p. 113)

7, *8*—*Homagnostus* sp. indet. *7*, best preserved cephalon, ×4; *8*, unique pygidium, ×2. (p. 110)

9–11—*Terranovella gelasinata* Shaw, n. sp. Dorsal, anterior, and lateral view of pair of fused free cheeks, ×2. (p. 104)

12–16—*Pseudagnostus araneavelatus* Shaw, n. sp. *12*, *14*, Cephala, ×9; *13*, cephalon retaining "webbed" surface, ×12; *15*, short holotype pygidium, ×9; *16*, fragmentary pygidium showing "webbed" surface, ×12. (p. 113)

17–22—*Pseudagnostus bilobus* Shaw, n. sp. *17*, *18*, cephala, ×9; *19*, second smallest cephalon found, showing more quadrate shape of immature head, ×9; *20*, holotype pygidium, ×9; *21*, *22*, pygidia showing variations in shape, ×8, ×5. (p. 112)

expanded forward; preglabellar median furrow generally present in Middle and early Upper Cambrian forms, but absent in later ones; surface smooth, corrugate, or granulate."

M'Coy used the subfamily ending because he regarded all trilobites as belonging to a single family, the Trilobitidae, which he divided into several subfamilies, among them the Agnostinae.

Subfamily AGNOSTINAE Raymond, 1913

Agnostinae RAYMOND, 1913, *in* Zittel-Eastman Textbook of Paleontology, p. 710.
Agnostinae KOBAYASHI, 1939, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 5, pt. 5, p. 159.

Agnostidae with glabella divided into two or three lobes. Axial lobe of pygidum divided into three lobes and rounded posteriorly. A median preglabellar furrow is commonly present, as are posterolateral spines on the pygidium. Surface smooth or furrowed.

Kobayashi lists this subfamily as new in his publication, but Raymond used it in the sense of a subdivision of the Agnostidae, so Kobayashi's use is merely an emendation. Raymond credited the subfamily to Jaekel, but a review of Jaekel's article shows that he did not split the Agnostidae into named subfamilies. If there is an earlier use of the name than that by Raymond, it has escaped my attention.

Genus HOMAGNOSTUS Howell, 1935

Homagnostus HOWELL, 1935, Wagner Free Inst. Sci. Bull., vol. 9, no. 2, p. 15.
Armagnostus HOWELL, 1937, Geol. Soc. America Bull., vol. 48, no. 8, p. 1162.

Genotype.—Agnostus pisiformis obesus Belt, 1876.

Agnostinae with large pygidial axis whose posterior lobe is inflated.

HOMAGNOSTUS sp.
Plate 24, figures 7–8

Diagnosis.—This species differs from the genotype only in having the furrows less well impressed.

Description.—Cephalon typical of the subfamily, wider than long, with sides tapering slightly, rounded in front. Glabella bilobed, with anterior lobe slightly narrower than main lobe. Basal glabellar lobes and median tubercle present. Rim narrow and of even width.

Pygidium wider than long, broadly rounded posteriorly. Rhachis does not extend to marginal furrow; rhachis inflated and evenly rounded posteriorly. Faint corrugation on pygidium. Pygidial spines reduced to minute swellings on rim.

This is the largest agnostid in the faunule.

Remarks.—This species is close to the genotype in construction except for the obsolescence of the furrows. It is possible that with more material this form might be recognized as a distinct species, but it is represented in the collections by only four cranidia and a single pygidium, clearly an insufficient number of specimens on which to base a new species.

The measurements obtained from the four cephala are listed below. The first measurement in each group is the "type" cephalon. All measurements are in millimeters.

Total length of cephalon: 3.8; 1.5; 5.5; 2.3; glabellar length: 2.7; 1.1;—; 1.6; width across basal glabellar lobes: 2.1; 0.8; 3.2; 1.1; width of anterior glabellar lobe: 0.9; —; —; 0.5; distance from rear of glabella to glabellar furrow: 1.9; 0.8; —; 1.1; maximum width of cephalon: 3.9; 1.5; 6.0; 2.2.

Measurements in millimeters on the unique pygidium are: Total length: 6.2; length of rhachis: 5.5; maximum width: 7.4; anterior width of rhachis: 3.1.

Subfamily GERAGNOSTINAE Howell, 1935

Geragnostidae HOWELL, 1935, Jour. Paleontology, vol. 9, no. 3, p. 231.
Geragnostidae KOBAYASHI, 1937, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 4, pt. 4, pp. 453–458.
Geragnostinae KOBAYASHI, 1939, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 5, pt. 5, pp. 166–167.

Agnostidae with rounded cephalon, lacking median furrow. Glabella bilobed, with transverse furrow well marked or faint. Accessory basal lobes on glabella. Pygidium round with lateral spines. Axial lobe of pygidium falls short of rear margin; it is trilobed. Posterior lobe of pygidial axis rounded but only rarely bulbous.

Genus GERAGNOSTUS Howell, 1935

Geragnostus HOWELL, 1935, Jour. Paleontology, vol. 9, no. 3, p. 231.

Genotype.—*Agnostus sidenbladhi* Linnarsson, 1870 (not 1869).

Geragnostinae with long glabella and rhachis.

Subgenus MICRAGNOSTUS Howell, 1935

Micragnostus HOWELL, 1935, Jour. Paleontology, vol. 9, no. 3, p. 233.
Geragnostus (*Micragnostus*) KOBAYASHI, 1939, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 5, pt. 5, pp. 167–171.

Subgenotype.—*Agnostus calvus* Lake, 1906.

Geragnostus with well developed dorsal furrows and clearly bilobed glabella. Pygidium clearly trilobed. Test smooth.

GERAGNOSTUS (MICRAGNOSTUS) BISECTUS (Matthew), 1892 var. TYPICA Shaw, n. var.

Plate 23, figures 12–18;
Plate 21, figure 18

Agnostus bisectus MATTHEW, 1892, Royal Soc. Canada Trans. for 1891, sec. 4, vol. 9, p. 50, pl. 13, figs. 2a, b.
Micragnostus bisectus HOWELL, 1935, Jour. Paleontology, vol. 9, no. 3, p. 233.
Geragnostus (*Micragnostus*) *bisectus* KOBAYASHI, 1939, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 5, pt. 5, pp. 168, 170, 183.

The separation of the two varieties of *G. bisectus* to be described is based upon a statistical analysis. The quantitative data will be presented in a later paper.

Description.—Cephalon elongate, smoothly rounded in front and narrowly rimmed all around. Dorsal and marginal furrows well impressed. Glabella bilobed, slightly pointed in front, parallel-sided. Anterior lobe slightly narrower than main lobe. Rear of glabella evenly rounded, terminating in front of rear edge of cephalon. Basal glabellar lobes well marked, triangular. Cheeks smooth, convex, confluent in front. Presence of lateral cephalic spines not established, for in all specimens the posterior cephalic margin is poorly preserved so that any spines which may have been present are destroyed. One specimen of the other variety, described below, does bear a spine, however.

Thorax unknown.

Pygidia are so variable in their structure that it is impossible to separate those forms belonging to the typical variety from those of *G. bisectus* var. *brevis*. A glance at the figures (pl. 23, figs. 14–18) will show that the forms at the extremes of variation are quite unlike one another, but the series is continuous between them and there are not two statistically separable groups.

Pygidium rounded, bearing lateral spines. In specimens shorter than about 2.3 mm. the length commonly exceeds the width. In larger specimens the proportion is reversed. Dorsal and marginal furrows well marked. Rim wider posteriorly than laterally. Rhachis trilobed, but with furrow separating middle and posterior lobes commonly obscure. Anterior lobe reduced to a pair of subrectangular lateral lobes separated by forward extension of middle lobe. Middle lobe also bears on its rear edge an elevated node, obscuring the central portion of the second transverse furrow; middle lobe narrower than anterior or posterior lobes, giving rhachis a "pinched-in" appearance.

Posterior axial lobe shows greatest variability. In 10 specimens it is slightly longer than wide, or of equal length and width, and rounded in the rear. In eight specimens it is slightly pointed. An extreme example of the rounded type is the bulbous specimen shown on plate 23, figure 15; there are two such specimens, but transitional forms are found in the 10 more "normal" pygidia. At the other extreme is the unique specimen with a sharply pointed rhachis shown on plate 23, figure 18. The elongation in this specimen is somewhat heightened by lateral compression, but the acuteness of the rhachis is primarily original.

Comparison with other species.—*Geragnostus bisectus* is similar to *G.* (*M.*) *subobesus* (Kobayashi), 1936, *G.* (*M.*) *rudis* (Salter) var. *holmi* (Westergård), 1922, and *G.* (*M.*) *hoeki* Kobayashi, 1939. It differs from the first in having a longer pygidium, from the second in lacking a tubercle on the glabella, and from the last in the structure of the two anterior lobes of the rhachis.

It is interesting to note that the South American species, *G.* (*M.*) *hoeki*, shows a similar dimorphism of the cephalon, having both the elongate and short forms. In this species, also, a single pygidium has been assigned to the two cephala.

GERAGNOSTUS (MICRAGNOSTUS) BISECTUS (Matthew) var. BREVIS Shaw, n. var.
Plate 23, figure 11

This variety is based upon four specimens in which the length of the cephalon is proportionately less, when compared to the cephalic width, than in the typical variety. The variety *brevis* is recognizable by the semicircular pattern of the cheeks, whereas the cheeks are U-shaped in variety *typica*. The separation into varieties is justified by a statistical analysis which indicates that in spite of the small size of the sample, the difference is highly significant. The difference is not due to the age of the specimens, for they are neither the smallest nor the largest of those at hand.

In spite of the sharpness of the division between the two groups, however, the differences do not seem to be great enough to warrant specific separation. This seems to be an example of intraspecific dimorphism.

The qualitative description of the typical variety applies equally to the short-headed variety. The type cephalon of the short variety retains a posterolateral spine.

Subfamily PSEUDAGNOSTINAE Whitehouse, 1936

Pseudagnostidae WHITEHOUSE, 1936, Queensland Mus. Mem., vol. 11, pt. 1, pp. 97–99.
Pseudagnostidae KOBAYASHI, 1937, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 4, pt. 4, pp. 449–451.
Pseudagnostinae KOBAYASHI, 1939, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 5, pt. 5, pp. 156–157.

Agnostidae in which the posterior lobe of the rhachis is obsolescent or obsolete, and in which there is developed a pair of diagonal accessory furrows defining a posterior pseudolobe.

Genus PSEUDAGNOSTUS Jaekel, 1909

Pseudagnostus JAEKEL, 1909, Deutsch. geol. Gesell. Zeit., Bd. 61, Heft 3, p. 400.
Plethagnostus CLARK, 1923, Canadian Naturalist, vol. 37, no. 7, p. 124.
Pseudagnostus KOBAYASHI, 1937, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 4, pt. 4, pp. 451–453.
Pseudagnostus KOBAYASHI, 1939, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 5, pt. 5, pp. 157–159.

Genotype: *Agnostus cyclopyge* Tullberg, 1880.

Pseudagnostinae with a smooth test.

PSEUDAGNOSTUS BILOBUS Shaw, n. sp.
Plate 22, figure 10; Plate 24, figures 17–22

Diagnosis.—*P. bilobus* is characterized by the presence of well-defined posterior accessory lobes on the rhachis and nearly or quite obsolete diagonal accessory furrows.

Description.—Cephalon typical of the family but more quadrate than in most species. Rim wide, square anteriorly, convex, separated from cheeks by a wide, shallow marginal furrow. Median furrow visible in all specimens but more strongly marked where exfoliated. Glabella tapers anteriorly. Anterior two pairs of glabellar furrows joined at center, forming X-shaped groove, isolating pair of subtriangular accessory lateral lobes, depressed below level of posterior glabellar lobe. X-shaped groove obsolescent in specimens retaining test but distinct where exfoliated. Posterior pair of glabellar furrows directed backwards, cutting off pair of triangular basal lobes which are displaced laterally. There are no posterolateral spines.

Thorax unknown.

Pygidium differs in detail from the fundamental pattern of the genus. Diagonal accessory furrows that ordinarily characterize the genus appear on only one of the 10 specimens in the type lot. Axial lobe well defined all around by dorsal furrow instead of being obsolete posteriorly as in other species. Another variation is the presence of a pair of prominent posterior accessory lobes behind the pygidial axis; these two lobes, which are ordinarily lacking in other species, give *P. bilobus* its trivial name. Rhachis prominent posteriorly, separating the posterior accessory lobes. Pleural lobes smooth except in the unique specimen bearing the accessory diagonal furrows.

Some of the specimens bear a wide, shallow furrow extending directly back from the axial lobe. This furrow is commonly absent on the outer surface and is poorly marked, even on exfoliated specimens; it is present

for varying distances behind the axial lobe but never extends more than two-thirds of the distance to the marginal furrow. Directly behind this furrow and just within the marginal furrow is a low, round knob, whose function is not understood. The knob does not seem to be homologous with the "cusps" (Kobayashi, 1939, p. 81) found on *Agnostus fallax tricaspis* Brögger, 1878, *A. pisiformis rugulosus* Matthew, 1898, and *A. pisiformis affinis* Matthew, 1898, because the "cusps" are developed from the rim, whereas the knob on *P. bilobus* is on the pleural lobe.

Pygidial rim convex, marked off by a broad shallow marginal furrow. Slender marginal spines extend slightly beyond the rear margin of the pygidium.

Comparisons.—*P. bilobus* is closest in appearance to *P. josephus* (Hall), 1863, and *P. cyclopyge* (Tullberg), 1880. It differs from both in the presence of accessory lobes behind the rhachis, from *P. josephus* in its lack of genal spines, and from *P. cyclopyge* in the general structure of the glabella and in the more quadrate cephalon.

PSEUDAGNOSTUS ARANEAVELATUS
Shaw, n. sp.
Plate 24, figures 12–16

Diagnosis.—This species differs from others in the genus in having the diagonal accessory furrows on the pygidium obsolete, and in having a short, prominent axial lobe on the pygidium. The cephalon lacks a preglabellar furrow.

Description.—The cephalon of *P. araneavelatus* is almost identical with that of *P. bilobus* save for the greater effacement. The median preglabellar furrow is lacking and all glabellar furrows are faint or obsolete. Accessory lateral lobes are not clearly defined on the glabella, but are indicated only by slight swellings on either side. The posterior pair of furrows is faint.

Thorax unknown.

Pygidium transverse, highly convex. Rim relatively wide, giving a subquadrate appearance because of thickening of its corners. Minute lateral spines. Marginal furrow deep. Pleural lobes globular, confluent, with semicircular posterior outline. Diagonal accessory furrows which normally characterize the genus are reduced to slight pits in dorsal furrow. Axial lobe reduced to short, wide, prominent protuberance, pointed posteriorly. Sides of rhachis straight, parallel or slightly divergent anteriorly.

Surface of some specimens of pygidia and cephala display fine web of inosculating ridges (pl. 24, figs. 13, 16) which has suggested the trivial name *araneavelatus*, which means "covered with a cobweb."

Comparison with other species.—*P. araneavelatus* differs from other species of *Pseudagnostus* by reason of its short transverse pygidium, which lacks diagonal accessory furrows and bears a short, prominent axial lobe. *P. araneavelatus* and *P. bilobus* differ in the structure of the rhachis. *P. latus* Kobayashi, 1938, from the "*Parabolinella* limestone" of southwestern British Columbia, is like *P. araneavelatus* in all respects save the prominence of the rhachis.

The only other species of *Pseudagnostus* that lacks the preglabellar furrow is *P. douvillei*, an Asiatic form, unlike *P. araneavelatus* in other respects.

POSITION UNCERTAIN
Genus LITAGNOSTUS Rasetti, 1944

Litagnostus RASETTI, 1944, Jour. Paleontology, vol. 18, no. 3, p. 234.

Genotype.—*Litagnostus levisensis* Rasetti, 1944.

Rasetti's description: "Agnostids with both shields presenting an extremely simple structure. Cephalon without a defined glabella, faintly rimmed. Pygidium without a defined rhachis, with a wider rim than the cephalon. Small median tubercles may be present on either shield."

LITAGNOSTUS RAYMONDI
Shaw, n. sp.
Plate 24, figure 6

Phalacroma parilis RAYMOND, 1924 (not *Agnostus parilis* Hall, 1863), Boston Soc. Nat. History Proc., vol. 37, no. 4, p. 396, pl. 12, fig. 8.
Phalacroma parilis RAYMOND (not Hall), 1925, Rept. Vermont State Geologist for 1923–1924, p. 143, pl. 12, fig. 8.

As Raymond pointed out, this species lacks the furrows found in "*Agnostus*" *parilis* Hall, 1863 (Hall, 1863, pl. 10, figs. 23–24; Walter, 1927, pl. 10, figs. 10–11) so it is here recognized as a distinct species, closely allied to *L. levisensis*.

Diagnosis.—This species differs from the genotype in having a narrower rim.

Description.—Shield entirely smooth save for a low tubercle. Rim narrow. A single specimen is illustrated and is oriented as a cephalon, but as is often the case with smooth agnostids, it is not clear whether the shield is a cephalon or a pygidium. There are less than 10 specimens in the collection, and none shows any clear distinction between head and tail.

Holotype.—Yale Peabody Museum No. 4753.

Pygidium No. 1
Plate 22, figure 18

A single small pygidium which may belong to *Plicatolina kindlei* has been found, but it is left unassigned for the present. It is transverse, with a relatively wide axial lobe, which reaches to the rear of the pygidium. There are four rings on the rhachis, excluding the articulating half-ring. Pleural lobes marked both by pleural furrows and interpleural grooves.

Measurements on this unique specimen are: Maximum width 1.80 mm.; width of axial lobe at anterior ring 0.64 mm.; maximum length (airline) 0.78 mm.

Pygidium No. 2
Plate 22, figure 19

Another unique pygidium cannot now be assigned to a species. It is transverse and has a wide axial lobe which does not reach the rear margin. There are three complete and two incomplete rings on the rhachis, plus a terminal segment. Pleural furrows and interpleural grooves are both marked. The margin is entire.

This specimen may belong to *Terranovella gelasinata*, for, if Pygidium No. 1, does belong to *Plicatolina kindlei*, only *T. gelasinata* is left without an assigned pygidium.

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SHANTUNGENDOCERAS AND THE ANTIQUITY OF THE ENDOCEROIDS

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SUN (1937) described from the zone with *Eoorthis* and *Changia sinensis* (Upper Cambrian), three species of cephalopods which he assigned to the genus *Shantungendoceras*, and regarded as the oldest of the true endoceroids. Several years later, (Flower, 1941, 1947) I proposed that the oldest true endoceroids were middle Canadian in age. I did not at that time refer to Sun's paper, because I hoped that in the meantime some of our Chinese colleagues would undertake a more thorough study of this form, exceedingly significant because of its age, and partly because I wished to avoid the tedious and not altogether pleasant task of casting doubt upon work based upon material I had been unable to examine.

However, because of the apparent conflict in views, it seems desirable to publish the reasons for rejecting *Shantungendoceras* as a Cambrian endoceroid, and at the same time to urge that the material be restudied from oriented sections, and preferably from thin sections, as soon as possible.

Sun regards *Shantungendoceras* as having a subcentral holochoanitic siphuncle containing endocones. It is necessary to point out that the evidence of the subcentral siphuncle, the holochoanitic wall, and the presence of endocones is extremely unconvincing. This is shown by the following analysis of his published material.

S. conicum is based upon one natural weathered section, a longitudinal section of a phragmocone of uncertain orientation. The apical camerae are filled with calcite, inorganic by all analogy. Orad of this portion, a tube extends orad for some distance. This tube is central in the section. Orientation of the shell has not been demonstrated. If the section is vertical, the siphuncle is central; if it is a transverse longitudinal section, the siphuncle may as easily be marginal. The structures within the tube are not clear, the photograph showing unfortunately very little contrast, but appear to be better interpreted as diaphragms than as endocones. They may be inorganic.

S. nanshanense is represented by several specimens, shells which are slender and straight or very nearly so. The material which Sun interprets as stereoplasm appears to be inorganic calcite filling some of the camerae; it shows none of the features of organic cameral deposits. Sun has interpreted an indistinct subcentral linear tube (shown in his figure 3a), as a subcentral siphuncle. Experience with similarly preserved cephalopods in the Canadian leads me to suspect that this is a completely inorganic structure. Instead, fig. 3c shows what I believe to be an essentially vertical section (the orientation of fig. 3a is uncertain). On this interpretation, the shell is very slightly curved endogastrically, and on the concave side there is a tubular structure which may very well be the siphuncle. Indeed, these sections are extremely similar to specimens of *Ectenoceras* which I have observed in lower Canadian limestones

S. ? curvatum is based upon a more slender and more curved shell. Sun compares it with *Plectronoceras* because of its curvature, and remarks that it can be distinguished by the marginal siphuncle of *Plectronoceras*. However, the figure fails to show a central siphuncle. Instead, near the middle of the specimen there is a part of the section showing clearly a tube, evidently a siphuncle, lying close to the concave side of the shell. Again the appearance of the section is indistinguishable from that presented by some of my own material of lower Canadian *Ellesmeroceras* and *Ectenoceras*.

It is regrettably necessary to conclude that the illustrations do not justify Sun's conclusions either as to the presence of endocones or the central position of the siphuncle. I should hesitate to publish these views were it not that such sections can be

duplicated in my own material among forms which are demonstrably not endoceroids but ellesmeroceroids. Sun's material should be restudied, with regard to the orientaton of these natural sections. It is to be suspected very strongly that the siphuncle is marginal and not central, further, that it lies close to the side of the shell which is faintly concave. Elsewhere, below the middle Canadian, there is no departure as yet known from this pattern. Further, polished sections are needed through the siphuncle to demonstrate (1) the nature of the siphuncle wall which Sun apparently assumed to be holochoanitic and (2) the nature of the organic deposits, if any, within the cavity of the siphuncle.

It should be pointed out in defense of the work of Dr. Sun, which I regard with the greatest admiration, that there was no basis at the time of his description for suspecting many of these matters. Indeed, his paper was colored by opinions then quite generally entertained. The endoceroids and the holochoanites were long regarded as the primitive cephalopods. Indeed, the first opposition to this view and the primitive nature of what are now known broadly as the ellesmeroceroids, was first voiced by Kobayashi at nearly the same time (1935, 1935A). Indeed, Kobayashi failed to note in this connection that the oldest of his endoceroids lacked holochoanitic structure.

Volborthella was accepted as a primitive cephalopod, a view not generally held at present by students of cephalopods. Schindewolf, in maintaining that *Volborthella* is a cephalopod, is nevertheless unable to connect it at all closely with any other type, and in his latest paper on the subject (1942) his diagram of the phylogeny fails to show any connection between *Volborthella* and higher forms.

It is implied by Sun's diagram that the siphuncle is central in primitive cephalopods. We have (ignoring *Volborthella*) no cephalopods below the base of the upper Canadian with central siphuncles; instead the siphuncle is marginal. There is after all no inherent reason why this should not be so. The idea of a primitive central siphuncle stems from the concept that typical "*Orthoceras*" is primitive. However, the cephalopods are fundamentally bilaterally symmetrical organisms; the primitive siphuncle may be expected to lie within the median plane of the organism, but there is no inherent reason why it should be located half way between the dorsum and the venter. On stratigraphic evidence alone the marginal siphuncle seems to be primitive, for it is universal among the lower Canadian (Wanwanian) faunas, as well as in the Cambrian *Plectronoceras* and *Shelbyoceras*. Indeed, a central siphuncle should not be primitive unless the animal that produced it was radially instead of bilaterally symmetrical.

My own investigations, (1941, 1947) much to my surprise showed that the holochoanitic siphuncle was not primitive. Indeed, thin sections of middle Canadian endoceroids showed short septal necks and thick connecting rings very similar to those of the older Ellesmeroceratidae of the lower Canadian. To such an ellesmeroceroid pattern had been added cones within the siphuncle. In this way the endoceroid pattern was developed, and we have yet to find evidence of a holochoanitic siphuncle wall in anything older than the upper Canadian piloceroids.

A further surprise in the same investigation was the retention of the connecting ring in the holochoanitic cephalopods, not only in the Canadian Piloceratidae, but throughout the younger Endoceratidae, none of which are known below the Chazyan. The connecting ring can be explained only on the assumption that the long holochoanitic necks were a specialized feature, derived from the siphuncles of the ellipochoanitic pattern. Further support of this view was found in the parallel between the zoned connecting ring, and rings containing the eyelet, in ellesmeroceroids, the ellipochoanitic endoceroids (Proterocameroceratidae) and the holochoanitic forms (Piloceratidae and Endoceratidae).

It should be mentioned that the same discovery made untenable the idea proposed by Grabau (1919) that the siphuncle of the endoceroids was the homologue of the entire shell of the other cephalopods and of *Volborthella*.

Shantungendoceras, from the present available evidence is probably an ellesmeroceroid, with a marginal tubular siphuncle, possibly possessing diaphragms, and by all analogy,

the siphuncle wall is ellipochoanitic. Indeed, there is no good basis for separating these forms generically from a group of closely allied slender ellesmeroceroids as *Stemtonoceras* and *Ectenoceras*.

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NOMENCLATURAL NOTES

ON A SUGGESTION RECEIVED BY THE INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE

(Commissions' reference Z. N. (S.) 372)

FRANCIS HEMMING, C.M.G., C.B.E. Secretary to the International Commission on Zoological Nomenclature

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The object of the present note is to elicit the views of zoologists on the question whether it is desirable to maintain or to modify the provision in the Règles that a trivial name published in a specific synonymy thereby acquires rights under the Law of Priority as an objective synonym of the name of the nominal species in the synonymy of which it was so published and accordingly (a) is available to become the valid name of the species in question if later it is found that the earlier name in the synonymy of which it was published is invalid as a junior homonym of some other name consisting of the same word, and (b) renders invalid as a junior homonym any later different use of the same specific trivial name in combination with the same generic name.

2. *The reason why this question is brought forward at the present time:* The reason why the foregoing question is brought forward and the views of specialists sought is that, as Secretary to the International Commission on Zoological Nomenclature, I have received a letter from a distinguished specialist in vertebrate zoology, urging that the Commission should recommend the Congress to reverse the present rule, on the ground that in his particular speciality the application of that rule leads in certain cases to the result (1) that a trivial name bestowed in manuscript upon a particular specimen but later published by the author concerned for the species represented by that specimen is not available for that species, because in the meantime the manuscript name in question has been erroneously published in the synonymy of some other species, and (2) that, as such publication in a synonymy has been ignored by later authors, confusion would result from the application of the present rule, which he accordingly recommends should be repealed. In the absence of information as to what is the general practice of specialists in relation to the ruling given in Opinion 4, it is not possible to form any considered opinion on whether particular cases of the kind described above could best be dealt with, and confusion prevented, by the use by the Commission of its plenary powers, or whether, on the other hand, the better course would be to secure the approval of the Congress for the repeal of this provision in Article 25. If that course were to be followed, some use of the plenary powers would, no doubt, also be required to provide a valid standing for trivial names published in specific synonymies and since brought into general use (through the name with which the unpublished name was synonymised having been found to be an invalid homonym), since if that were not done, unnecessary confusion and name-changing would result from the proposed amendment of article 25 although that amendment had, as its express object, the prevention of confusion and unnecessary name-changing as the result of the strict application of the Règles.

3. *The origin and present status of the existing rule:* The rule that a trivial name published in a specific synonymy acquires availability under both the Law of Priority and the Law of Homonymy in virtue of being so published was first promulgated in 1907 when the Seventh International Congress of Zoology at its meeting held in Boston, Massachusetts, approved Opinion 4 rendered shortly previously (but not until then published) by the International Commission on Zoological Nomenclature. This provision has therefore been part of the international system of zoological nomenclature for over forty years. When in 1948 the Thirteenth International Congress of Zoology incorporated into the Règles the

rulings in regard to the Règles given in Opinions previously rendered by the International Commission, it so incorporated the provision now under consideration (1950, Bull. Zool. Nomencl. 4: 145–146). This provision will accordingly appear in the text of the Règles as amended by the Paris Congress, when that text is published.

4. *The validity of the ruling given in Opinion 4 not a relevant issue:* The ruling in Opinion 4 that a trivial name published in a specific synonymy thereby acquired rights under the Law of Priority has occasionally been criticized on the ground that it was inconsistent with the general provisions of Article 25 and was therefore ultra vires and invalid. But once Opinion 4 had been approved by the Congress (as it was in 1907) the possibility of its being ultra vires was no more open to questions than that of any Article in the Règles. That this is the position was reaffirmed by the express decision of the Paris Congress to include this provision in the revised text of the Règles.

5. *The only issue which remains to be considered:* The only issue which remains to be considered is therefore whether the provision in question is in harmony with the general needs of zoologists and palaeozoologists, and, if not, in what direction it is desirable that the International Commission on Zoological Nomenclature should recommend the Fourteenth International Congress of Zoology to amend this provision at its meeting to be held in Copenhagen in 1953.

6. *The present issue in relation to stability in zoological nomenclature:* As already noted, the provision with which we are here concerned has formed part of the international system of zoological nomenclature for over 40 years. Clearly, therefore, the first matter on which it is essential that the International Commission should inform itself is what is the general practice of zoologists and palaeozoologists in this matter. It is possible that the practice of specialists in one group differs from that of specialists in another. What the Commission needs first to ascertain is what is the general practice of specialists working in each of the various groups of the Animal Kingdom, for clearly the question whether the ruling given in 1907 that a trivial name published in a specific synonymy is to be accepted as possessing rights under the Law of Priority has since been generally accepted or alternatively has been widely overlooked or disregarded is of cardinal importance in any consideration of this question, having regard to the over-riding need of avoiding any action which might give rise to instability in zoological nomenclature.

7. *Scope of the present inquiry:* In the actual case which has been brought to the attention of the Commission and which has given rise to the present inquiry, the problem raised was in relation only to the status of a trivial name bestowed on a specimen in manuscript when the first occasion on which that name is published is in a specific synonymy. It would clearly not be possible to limit any change of the Règles to this limited class of name, for manuscript names have in the past often been published in this way without any indication on the part of the author by whom they were published, whether he was aware that the name in question was still an unpublished manuscript name or whether he believed that that name had already been validly published either by the author by whom the name had been originally proposed in manuscript or by some other author. Any new provision (like the existing provision) would therefore need to apply to all trivial names, when first published in specific synonymies, for it would be wrong in principle and unworkable in practice to devise a provision, the application of which called for a subjective decision on the part of the reviser on the question whether an author who published a manuscript name in a specific synonymy was or was not aware that the name which he so published was or was not an unpublished manuscript name previously proposed by some author. Moreover, a change limited in the foregoing manner, even if that were practicable, would not meet the point which has been raised, for it has often happened that the first time that a manuscript name has appeared in print it has done so as a nomen nudum and that it was only when it was next published that it appeared in a specific synonymy. It seems evident therefore that, if any change were to be made in the present rule, it would need to apply to all trivial

names first published in specific synonymies; it would therefore have to cover (a) any name originally proposed in manuscript which, when first published, was published in a specific synonymy by the author by whom it had originally been proposed in manuscript; (b) any name published conditionally as a possibly needed nomen novum (substitute name) or as an emendation of the trivial name with which it is synonymised.

8. *Need for avoidance of name-changing while the present question is under consideration:* In this, as in other cases of a similar kind, it is important that there should be no disturbance in existing nomenclatorial practice while the question of principle involved is under consideration, for premature name-changing of this kind would run counter to the expressed desire of the Congress that all unnecessary name-changing should be avoided.

9. *Questions on which it is desired that specialists should furnish information:* In the light of the foregoing considerations specialists are urged to furnish the Commission with answers to the following questions:

(1) Do you in your work accept as an available name (that is, as a name possessing rights under the Law of Priority and the Law of Homonymy) a trivial name originally published in a specific synonymy?
(2) Do other specialists in your field treat such a trivial name in the same way that you do?
(3) In what branch of the Animal Kingdom are you a specialist? NOTE: please answer this question as precisely as possible and indicate also whether you work on living forms or on fossils.
(4) (To be answered only by those specialists whose answer to question 1 is "yes"): Do you consider that confusion and name-changing would result in your special field if the Règles were altered in such a way as to render unavailable a trivial name published in a specific synonymy?
(5) (To be answered only by those specialists whose answer to question 1 is "no"): Do you consider that confusion and name-changing would result if the present rule that a trivial name published in a specific synonymy thereby acquires availability were to be strictly applied to specific names in your special field?

10. *Return of replies to the foregoing questions:* It is particularly hoped that as many zoologists and palaeozoologists as possible will furnish replies to the foregoing questions; further, it is hoped that specialists will be good enough, when answering Question 4, or, as the case may be, Question 5, to cite definite examples of cases where they apprehend that confusion would arise in the circumstances there stated. All replies to the foregoing questions should be clearly marked "Z. N. (S) 372" and should be addressed to Francis Hemming, Secretary, International Commission on Zoological Nomenclature, at 28 Park Village East, Regent's Park, London N.W. 1, England.

EDITOR'S NOTE.—In order to secure rapid publication this communication was sent to the printer without revision on the day of receipt, December 8, 1950.

SOME COMMENTS ON VECCHIA, "SU ALCUNI NOMI GENERICI DI AMMONITI LIASSICI"

OTTO HAAS
The American Museum of Natural History, New York

Dr. Orlando Vecchia's above article (1949b) was prompted by a brief note of mine in this Journal (1947) and examines, accordingly, all three of the nomenclatorial problems dealt with in the latter.

1. *Arieticeras* vs. *Seguenziceras*

Vecchia now agrees with me in rejecting Levi's proposal to replace *Arieticeras* Seguenza, as allegedly preoccupied by Quen-

stedt, by *Seguenziceras*. It is true that in my note of 1947 I overlooked the fact that Dr. L. F. Spath seems to accept the name *Seguenziceras* in proposing (1924, p. 192) a new family Seguenziceratidae. Dr. W. J. Arkell (letter to the writer, dated December 22, 1949) also feels inclined to accept *Seguenziceras* for the reasons given by Levi. However, even in the face of these authorities I would still maintain the view that, regardless whether or not "*Arieticeras*" Quenstedt antedates *Arieticeras* Seguenza, no intention of proposing a scientific name of any kind was implied in Quenstedt's use of *Arieticeras* and that this use is, therefore, not apt to invalidate a later one, if meant seriously, as it was by Seguenza. Fucini (1900, p. 175) and Roman (1938, p. 112) also give *Arieticeras* preference over *Seguenziceras*, the latter with a motivation similar to the one given above.

2. *Fuciniceras* vs. *Hildoceratoides*

Vecchia's discussion of this problem invites the following comments:

(a) He considers my subgeneric diagnosis of *Fuciniceras* inconsistent with my selection of *Hildoceras lavinianum* (Meneghini) Fucini, 1901,[1] as its type species, since the latter, in his opinion, differs "substantially" from that diagnosis by its venter, which is said to be narrow but not wide, and by its ribs, which are said to become somewhat weaker on the body chamber and to be grouped in bundles of two, three, or even four rather than remaining single. In examining these alleged differences it might be well to state first that it is the specimen illustrated in Fucini's (1901, pl. 11) figure 7 to which Meneghini applied, according to Fucini (ibid., p. 53, last line but one), the name *Ammonites lavinianus* and which, therefore, must be considered the holotype of *Fuciniceras lavinianum*. This specimen, as distinct from the one illustrated in Fucini's figure 6, shows hardly any fading of the costation on the body chamber and, to judge by the photograph, only quite occasionally bifurcation of ribs. Its venter, seen in figure 7b, is not extremely wide, but it cannot be called narrow either. Thus, the holotype of *F. lavinianum* can well be accommodated within my subgeneric diagnosis which, in calling the venter "blunt, comparatively wide" (. . . mit stumpfem, verhältnismässig breitem Externteil), and in stating that the ribs are "single as a rule" and "do not decrease in strength toward not: on the body chamber" (. . . in aller Regel einfachen . . . Sichelrippen, die gegen die Wohnkammer hin an Stärke nicht abnehmen") leaves ample allowance for inclusion in *Fuciniceras* of forms like the holotype here discussed. This result receives strong support from Vecchia's (1949b, p. 5) inclusion of Fucini's varieties *conjungens* (1901, p. 54, pl. 12, figs. 2, 3) and *dissimilis* (1905, p. 96, pl. 3, figs. 13, 14) of *F. lavinianum* in *Fuciniceras*, particularly so if Fucini's narrow circumscription of species is taken into account. From the above it follows that there is no real inconsistency between my diagnosis of that subgenus and my selection of its type species.

(b) On the assumption, however, that they are incompatible, Vecchia raises the question whether the diagnosis or the selected type should be considered decisive for the interpretation of a proposed genus. He decides the question in favor of the diagnosis and, thus, arrives at the conclusion that *Fuciniceras* Haas, 1913, should be considered a nomen nudum or, better still, be valid only as *Fuciniceras* Fucini, 1931, with *F. meneghinianum* Haas replacing *F. lavinianum*, as proposed by Haas in 1913, as genotype.

This conclusion of Vecchia's appears to be quite untenable from a strictly nomenclatorial point of view. For the genotype is, and remains under all circumstances, the bearer of the generic name and it can by no means ever be replaced by any other species.[2] Nor can the type species—as was

[1] Vecchia is correct in stating that this species, named but never described nor figured by Meneghini, should properly be considered a species of Fucini's (1901, p. 52, pl. 11, figs. 6, 7). However, in naming this species this fact should be expressed as above. Vecchia's rendition "*F. lavinianum* (Fucini 1901, non Meneghini)" is likely to cause the wrong impression as if Meneghini's name were a junior homonym of Fucini's.

[2] Cf. Hemming, 1950, p. 8: "[The International Commission on Zoological Nomenclature] recommended—and the [International] Congress [of Zoology] in Paris 1948 agreed—that, once one of the originally included nominal species

attempted in the present case by Fucini (1929, p. 46) and recently by Vecchia (1949b, p. 5)—ever be transferred to any later genus. It might, however, be returned to the genus from which the one as whose type species it was designated was split off, if this separation is considered taxonomically unjustified. Thus, even if there existed a discrepancy between my diagnosis and my selection of a type species, it would not affect the validity of the genus (originally: subgenus) *Fuciniceras* Haas, 1913; only its diagnosis would have to be amended accordingly. Had Fucini done so, as he did not, in 1931, then the correct designation of the genus would have to read *Fuciniceras* Haas, 1913, emend. Fucini, 1931, but not *Fuciniceras* Fucini, 1931, as proposed by Vecchia (1949b, p. 5). It has, however, sufficiently been demonstrated in the preceding paragraph (a) that no such emendation was needed.

(c) It is not intended here to enter into the problem, thoroughly examined by Vecchia,[3] of the delimitation between the genera *Fuciniceras*, *Hildoceratoides* Buckman, 1921, and *Hildaites* Buckman, 1921,[4] except for restating that the transfer of *F. lavinianum* (*forma typica*) to *Hildaites* Buckman, now proposed in this connection by Vecchia, is, from the nomenclatorial angle, just as impossible as the one to *Hildoceratoides*, attempted by Fucini in 1929.[5]

3. Status of the generic (and subgeneric) names proposed in Fucini's Taormina monograph

This problem, raised by my note of 1947, is painstakingly re-examined by Vecchia who arrives at the conclusion that three of the generic names held invalid by me (*Fontanelliceras*, *Emaciaticeras*, and *Naxensiceras*) and one of those whose validity I questioned (*Bassaniceras*) can be maintained nomenclatorially. However, final judgment on this issue will have to await publication of the new official version of Art. 25 of the Rules, as amended by the International Zoological Congress of Paris, 1948 (see Hemming, 1950, pp. 4, 5). In the meantime, it would seem that even the liberalized version to be expected will not be able to save the names rejected even by Vecchia,[6] and I still doubt if it will support all those of Fucini's generic names established in part 4 of his monograph, published in 1931, which Vecchia proposes to maintain.

In concluding, I should like to emphasize my full agreement with Dr. Vecchia's (1949, p. 7), taxonomic evaluation, stating that "most of those names seem, in reality, not to indicate differences of much more than specific rank."

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has been duly selected as the type species of a genus, that type species should not be liable to be changed in the light of subjective taxonomic considerations."

[3] The results of this examination have been applied by Vecchia already in a faunal list of a slightly earlier paper (1949a, p. 107).

[4] Dr. Arkell (letter to the writer, dated December 22, 1949) considers *Hildoceratoides* a synonym of *Hildaites*.

[5] Here it might be added that Vecchia's (1949b, p. 4) censure of my raising the question of priority: *Fuciniceras* vs. *Hildoceratoides*, the two genera being distinct anyway, can be explained only by his having not fully understood my 1947 note. For there (p. 80) I wrote verbally that only "if there were not such a wide morphological difference" *Fuciniceras* Haas, 1913, would still claim precedence over *Hildoceratoides* Buckman, 1921.

[6] Of these, *Di-Stefania* is certainly invalid, since it is a junior homonym of *Distefania*, proposed by Vecchia-Rispoli, Boll. Soc. Zool. Ital., vol. 3, 1917, p. 174, for a Cenomanian crab. I am indebted for this reference to Major Claud W. Wright of London, England (letter to the writer, dated April 25, 1947).

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FOOTNOTE TO A FOOTNOTE

OTTO HAAS

The American Museum of Natural History, New York

The masculine gender of the adjectival form of *spina* is not "*spiniferus*," as assumed by Weller (1950, p. 509, footnote 8), but *spinifer*. (Cf. Bonnet, 1950, p. 186 [Propos. 8, Art. 15bis, 5(b)].) *Spiniger* is an alternate form.

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REVIEWS

LEHRBUCH DER PALÄOZOOLOGIE by Oskar Kuhn. Stuttgart, E. Schweizerbart'sche Verlagsbuchhandlung (Erwin Nägele) 1949. v + 326 pp., 224 figs., 50 pls.

To cover nowadays the whole field of paleozoology, both invertebrate and vertebrate, in a single volume amounting (exclusive of the index) to 314 pages only, a considerable part of which is absorbed, as it has to be, by figures and plates, is certainly not an easy task. On the whole, Professor Kuhn may be credited with having proved equal to this task, whose foremost difficulty may be seen in the application of about the same degree of condensation to all groups included, regardless of the author's personal preferences.

As pointed out in his preface, the author, to save space, purposely excludes "general paleontology," i.e., biostratonomy, problems of fossilization, index fossils, biostratigraphy, etc., and paleobiology, i.e., paleoecology, from the scope of his textbook. As might be expected from a declared anti-evolutionist,[1] the same holds true for phylogeny, but it may be doubted if such limitation makes the book more attractive for geologists and naturalists desirous of some general knowledge of paleozoology, whom it is meant to serve.

The first seven pages of the text deal with the contents of paleozoology and its delimitation from related sciences, such as neozoology, historical geology, and biostratigraphy, and with the concept of systematic morphology. The usual table of geological eras, periods, and epochs is added. Twenty-two "Grundbaupläne," roughly corresponding to phyla, are distinguished within the animal kingdom, twelve of which only are represented by fossils. In line with the author's previous work, his approach is strictly typological, emphasizing the "Bau plan" concept, as favored by Dacqué and Schindewolf, and the idealistic morphology of Troll and others. As far as transformism is admitted at all, Schindewolf's typostrophism, although not mentioned, seems to be favored.

The remaining 307 pages deal with the 12 phyla (now named "Kreise") of the Protozoa, Spongia, Cnidaria, Echinodermata, Aschelminthes, Homalopterygia, Annelida (the last three together occupying half a page only), Bryozoa, Brachiopoda, Mollusca, Arthropoda, and Vertebrata, with a little less than two-fifths of the text devoted to the last phylum, a ratio that should satisfy even an orthodox vertebrate paleontologist.

Given the size of this textbook, no attempt could be made at listing even the most important genera; rather could only a few, as representative as possible, be chosen from every group. To judge by this reviewer's sampling, the selection is, in general, well made, but the "telegram style" used, according to the preface, in the generic diagnoses is, in many cases, doomed to failure, making it impossible for the reader to form an idea of the genus' essential characters unless helped by an illustration. For example, characterization of the ammonite genus *Desmoceras* (p. 154) is restricted to the words: "without bifurcation of the indistinct ribs"[2] and no illustration is given. However, a specialist will think of *D.* as of an essentially smooth genus, whose type species, *Ammonites latidorsatus* Michelin, exhibits varices and growth striae, but no ribs. Another criticism that cannot well be suppressed is that this treatise's nomenclature is not up to date; thus, the name *Orthoceras* is still used (p. 140) despite everything that has been written in the last fifteen years to prove its unavailability.

It must be admitted, though, that the latter imperfection may be of minor importance to those users of the book for whom it is primarily destined. The abundance of well selected, clear illustrations, most of them reproductions of drawings and diagrams, deserves high praise. They

[1] See, e.g., the author's book "Die Deszendenz-Theorie," Bamberg (Meisenbach & Co.), 1947, 147 pp., 23 figs.

[2] Reviewer's translation.

will contribute a good deal to the usefulness of this book as an introduction to paleozoology for beginners, although it cannot be expected to be very helpful to the specialist.

An index of taxonomic names, covering the last 12 pages, greatly facilitates the use of this textbook.

OTTO HAAS

NEW EDITIONS OF TWO HANDBOOKS OF NOMENCLATURE

PROCEDURE IN TAXONOMY, by Edward T. Schenck and John H. McMasters, revised by A. Myra Keen and Siemon William Muller. Stanford University Press. 1949. 93 pp. $2.50.

EINFÜHRING IN DIE ZOOLOGISCHE NOMENKLATUR, by Dr. Rudolf Richter, zweite Auflage. Senckenberg-Buch 15. Frankfurt am Main. 1948. 252 pp. 8.50 DM.

That the Stanford PROCEDURE is again available will be good news for those dependent on books in English. The first edition was widely used and is well-known. Very few changes have been made in the body of the book, which remains a handy summary of taxonomic procedures, which can safely be recommended to students, although the more advanced of them will want to supplement the brief discussion allowed some debatable topics. Again, too, we have a handy printing of the International Rules of Zoological Nomenclature. The titles of the *Opinions* of the International Commission are given, and brief analyses of the first 133 are reprinted from the first edition.

For the later *Opinions*, the revisers have felt bound by the copyrighting of the Commission's publications, and give the titles only, except in cases where an Opinion had been reviewed, and the review could be quoted. In this I think the revisers were unwise, and under the influence of some of the mesmeritic legalisticism which occasionally seeps like a fog from the Commission's offices. There may be good technical reasons for having such material entered for copyright, but surely this technical procedure should not be invoked to prevent full discussion of material which the Commission has published on behalf of the zoologists of the world.

This little book has been useful, and will continue to be so.

Although Dr. Richter is no longer a member of the International Commission, for many paleontologists interested in nomenclature, where he sits will still be the head of the table. This new and enlarged edition of his Einführing will be welcomed by all. Nowhere else do we get such thoughtful and penetrating discussion, not only of the International *Rules* themselves, but also of the concepts underlying them and the thinking which led to their adoption. This book is for all taxonomists, but is of special value to paleontologists, since many of Richter's examples are taken from his own field.

The first 69 pages are given to detailed discussion of procedural points: the use of the nomenclatura aperta, citation of synonymies, use of standard abbreviations, and such matters. Much of this material has appeared in other papers by Richter, either separately or prefixed to taxonomic work, but it is valuable to have it thus compiled and at hand for reference.

Then follows the text of the *Rules* and, under each rule, a summary of the relevant *Opinions* and Richter's own interpretation of its meaning and application. These notes are very full (twenty-three pages are devoted to discussion of Rule 25) and correspondingly useful. One need not always agree with the author to appreciate the long consideration which lies behind his opinions, and to feel the stimulation of such opinions forcefully stated. The sections devoted to the thorny problem of homonymy will probably arouse most interest and debate.

The book concludes with the Official List of Generic Names, and of Genotypes. For anyone working in zoology, paleo- or neo-, this little book deserves the tag "indispensable."

May a Scot use this opportunity to object to the superstition, perpetuated by Richter, that the patronymic prefix *Mc* is an abbreviation of *Mac*, and that they are therefore alphabetically equivalent? It is true that *Mackay*, *MacKay*, *McKay* and *M'Kay* were all originally attempts to render a glottal stop in terms of English orthography, but they are now distinct names, and should be treated as such. Should I seek my name among the *Sa*'s, because my remote ancestors were too illiterate to know that the local land-owner spelt his name *St. Clair*? No. A name is a name, and I shall continue to put *MacKay* after *machinery*. My editors will continue to change it, but I shall feel better for the protest.

G. WINSTON SINCLAIR

NOMINATIONS FOR MEMBERSHIP

In accordance with Article 3, Chapter 1 of the By-Laws of the Paleontological Society, the Secretary submits the following applications for membership in the Society. They have Council approval.

ROBERT RAYMOND BERG, 483 Lynnhurst, Apt. 21, St. Paul 4, Minn. W. C. Bell, F. M. Swain.

RICHARD STANTON BOARDMAN, 205 W. Hill St., Champaign, Ill. H. R. Wanless, Bernhard Kummel, H. W. Scott.

M. N. BRAMLETTE, Dept. of Geology, University of California, Los Angeles, Cal. W. H. Easton, O. L. Bandy, U. S. Grant.

ROBERT BURTON BROCKHOUSE, 1602 Georgia Dr., Urbana, Ill. H. W. Scott, H. R. Wanless, B. Kummel.

JAMES LESLIE CONNELLY, JR., 101 Swallow Hall, University of Missouri, Columbia, Mo. A. G. Unklesbay, L. M. Wright, M. G. Mehl.

ELIZABETH KING DALVÉ, 3579 Washington Ave., Cincinnati, Ohio, R. H. Flower, K. E. Caster, F. D. Holland.

WAYNE ELLIOTT, 2426 Zandia Ave., Long Beach, Cal. W. H. Easton, O. L. Bandy, M. L. Natland.

EDWARD S. GILSON, R.F.D. 2, Cleves, Ohio. R. H. Flower, K. E. Caster, H. Dresser.

HORACIO J. HARRINGTON, Instituto de Geologia, Facultad de Ciencias Exactas, Fisicas y Naturales, Universidad de Buenos Aires, Argentina. K. E. Caster, R. C. Moore, C. E. Weaver.

HENRY F. HERPERS, JR., Box 1365, Short Hills, N. J. G. L. Jepsen, E. Dorf, B. F. Howell.

PORTER M. KIER, Museum of Paleontology, University of Michigan, Ann Arbor, Mich. G. M. Ehlers, E. C. Stumm, R. V. Kesling.

TEIICHI KOBAYASHI, Geological Institute, Faculty of Science, University of Tokyo, Japan. K. E. Caster, Winifred Goldring, H. E. Vokes.

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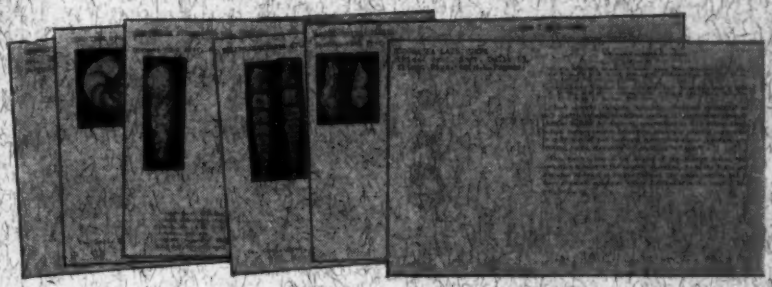

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